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Economics of Sugar-Beet Mechanization in California

BY WARREN R. BAILEY
Agricultural Economist
Bureau of Agricultural Economics

UNITED STATES DEPARTMENT OF AGRICULTURE
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PREFACE

A reduction in the amount of human labor required to produce a crop usually means lower cost of production. Hence, farmers have sought opportunities of substituting mechanical power for human power, and mechanization has become characteristic of farming in the United States.

Mechanization, however, has come very slowly in the production of sugar beets. Harvesting of sugar beets is now largely mechanized in California and is making rapid progress elsewhere, but much labor still is used in thinning the seedling stand and in hoeing. Mechanization of these operations, although it seems eventually assured, is progressing more slowly.

The economic significance of mechanization is the change wrought in the competitive position between crops. If mechanization makes a crop more profitable, production may expand on existing farms, or to other farms or other areas. An appraisal of the impact of sugar-beet mechanization is an objective of this report. The effect of mechanical harvest can now be assessed, but the probable effect of mechanized thinning and hoeing cannot be fully ascertained.

Comparisons are made among the costs, the labor requirements, and the investment, of hand and machine harvesting. Such economic questions are discussed as: Under what situations is mechanical harvesting feasible? How does amount of annual use of machines affect harvesting costs per acre? What minimum acreage justifies conversion to machine harvesting? The data presented pertain to California, but they may be useful as a guide in other sugar-beet producing areas where mechanization is less advanced.

This report is based on a study conducted cooperatively by the California Agricultural Experiment Station and the Bureau of Agricultural Economics. H. L. Stewart, Agricultural Economist, Bureau of Agricultural Economics, planned the broad phases of the study. For the University of California, R. L. Adams, Giannini Foundation of Agricultural Economics, assisted in the planning and offered many helpful suggestions; Rex D. Helfinstine, then Graduate Assistant, assisted in collection of data and in early phases of analysis; Roy Bainor, Division of Agricultural Engineering, reviewed the manuscript for content and technical engineering detail. Thanks go to the sugar companies, manufacturers and dealers of harvesters, and to farm advisors for information and advice freely given. The author appreciates the cooperation of the farmers who furnished much of the basic information.

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By Warren R. Bailey[1]

CONTENTS

Page
Introduction 1
Economic questions raised by harvest mechanization 4
Method and scope of study 4
Economic effects of harvest mechanization 5
  Effects on investment, labor requirements, and cost of harvesting 6
  Effects on organization and operation of farms 10
  Opportunities for further mechanization in production of sugar beets 12
  Probable economic effects of further mechanization 15
Performance and harvesting costs with mechanical harvesters 16
  Two-row, spike-wheel harvesters 17
  One-row, hand-sorting harvesters 31
Effect of yield per acre on harvesting cost per ton 38
Custom harvesting and renting machines as possibilities on small acreages 40
Additional tables 42

INTRODUCTION

Historically, production of sugar beets has required large amounts of manual labor for thinning the seedling stand, hoeing weeds, and topping and loading the beets at harvest. Until recently these operations required about 60 man-hours of labor per acre. Efforts to reduce this hand work by means of mechanization progressed slowly. Tractor power had replaced animal power, thereby reducing from 16 to 7 man-hours per acre during the period 1915–36, the total labor required in preparation of land and in planting, cultivating, and lifting beets (table 1). But, against a total requirement of 78 man-hours a saving of 9 was not impressive, and it did not free the producer from dependence on large numbers of hand workers at critical periods in the production cycle.

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[1] Agricultural Economist, Berkeley, Calif.

TABLE 1.—*Estimated number of man-hours required to produce an acre of sugar beets in California in specified years*

Operation	1915	1922	1932	1936
	Tons	*Tons*	*Tons*	*Tons*
Average yield per acre	10.2	7.4	12.4	13.8
	Man-hours	*Man-hours*	*Man-hours*	*Man-hours*
Prepare and plant	6.1	5.4	3.3	3.0
Cultivate and furrow	5.8	4.1	2.8	2.4
Irrigate	5.8	4.1	6.0	5.0
Lift	4.1	3.8	1.6	1.6
Haul	5.2	5.1	5.0	5.0
Contract operations	62.2	62.0	61.4	61.0
Total	89.2	84.5	80.1	78.0

MACY, L. K., and others. CHANGES IN TECHNOLOGY AND LABOR REQUIREMENTS IN CROP PRODUCTION—SUGAR BEETS. Report No. A–1, National Research Project, Works Progress Administration, Washington, D. C., August 1937, p. 30.

During the 1930's, research and experimentation was done on the problems of mechanizing production of beets. In some States growers attempted to use mechanical thinners, blockers, and weeders, but the new machines were not satisfactory for general adoption.[2] Some experimental models of harvesters removed beets from the ground but did not top them acceptably.

During World War II a big step toward eventual mechanization of sugar-beet production was the successful development of mechanical harvesters. Early in the war a shortage of labor plagued the beet industry. As partial relief the Government arranged to import Mexican Nationals, but still the need for machines to replace "stoop" labor was critical. This labor situation proved to be the catalyst needed to hasten development of harvesters. Manufacturers of machinery with the help of agricultural experiment stations, the United States Department of Agriculture, sugar companies, and farmers, took the more promising ideas from previous research, made new improvements, and finally developed several types of acceptable harvesters. Although harvesters did not become a practical reality until late in the war, they helped materially to relieve postwar labor shortages.

Mechanical harvesting has expanded rapidly, especially in California. Harvesters were first used commercially in 1943 when a one-row model passed the experimental stage. In 1944 a two-row model was introduced and during each of the next few years more machines and new or improved models were put in operation. In 1945 about 155 machines were in use and some 28 percent of the beets were harvested mechanically (table 2). During the next 3 years, mechanization spread so rapidly that in 1948 almost three-fourths of the acreage was harvested by machine. This high rate of mechanization is even more remarkable when it is remembered that these harvesters are expensive in comparison with most other farm machines. Mechanization on small farms, although less complete, has been aided by custom harvesting and the more recent introduction of cheaper, one-row machines.

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[2] In the Red River Valley of Minnesota-North Dakota, cross blocking and weeding became common practice about 1930.

TABLE 2.—*Extent of mechanical harvesting of sugar beets in California, 1945–51, and in major producing areas in 1948*

Year and area	Total harvested acreage [1]	Machine-harvested acreage [2]	Mechanical harvesters [3]	Percentage harvested by machine
	1,000 *acres*	1,000 *acres*	*Number*	*Percent*
1945	93	26	155	28.0
1946	122	63	340	51.6
1947	156	94	500	60.3
1948:				
Sacramento and North San Joaquin [4]	65	49		75.4
South San Joaquin Valley [5]	15	14		93.3
North Central Coast [6]	41	27		65.9
Southern California [7]	10	4		40.0
Imperial County	41	28		68.3
Total	172	122	570	70.9
1949	134	105	900	78.4
1950	209	157	1,240	75.1
1951	140	105	1,300	75.0

[1] Bureau of Agricultural Economics.

[2] Net acreage excluding headlands and roadways sometimes harvested by hand methods to open fields for mechanical harvesting, as reported by the sugar companies to the writer, except that 1949–51 was estimated from information furnished by the Farm Placement Service, California Department of Employment, Sacramento.

[3] Estimate based on number manufactured less estimated number becoming obsolete, worn out, or not used.

[4] Including San Joaquin and Contra Costa Counties, and others farther north.

[5] Including Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern Counties.

[6] Including Alameda, Santa Clara, Santa Cruz, San Benito, and Monterey Counties.

[7] Including San Luis Obispo, Santa Barbara, Ventura, Los Angeles, and San Bernardino Counties.

Mechanized harvesting of beets in California is now a generally accepted practice, not a makeshift device adopted in wartime to be discarded with the return of more labor. Growers buy machines now where once they preferred to rent them. Custom harvesting has expanded to a point at which mechanized harvesting is available to smaller growers who cannot afford to own machines. No thought is given to a return to hand methods, even though labor is again available. Growers generally feel that harvesters do acceptable work and that they have reduced the costs of harvesting.

During the war, sugar-beet growers also attacked the problem of thinning and weeding—the spring finger work. In Yolo and Monterey Counties a row blocker with a revolving cutter head was tried but it was not completely satisfactory for thinning and in the main it was discarded when labor became available again at the end of the war. The problem of mechanizing spring finger work remains largely unsolved; it is a more stubborn problem than was mechanical harvesting, but many believe that eventually it will be solved.

ECONOMIC QUESTIONS RAISED BY HARVEST MECHANIZATION

Now that mechanization of the beet harvest is almost complete we may well ask these questions:

1. To what extent has mechanization of harvesting reduced labor requirements and production costs?
2. Has mechanization made sugar beets a substantially more attractive crop to growers?
3. What is the competitive position of sugar beets for farm resources—land, labor, capital, and management?
4. Are sugar beets tending to displace other crops, and if so, what crops?
5. What opportunities remain for further mechanization and reduction of costs in production of sugar beets?

Eventual complete mechanization could change the entire competitive relationship between sugar beets and other crops, in areas in which production of beets is concentrated and also where beets are only a minor crop. But the economies resulting from mechanization may be too small to shift the competitive balance in favor of beets. Mechanization may be merely a "catching up" with crops already mechanized or otherwise in a more advantageous position. This report attempts, at least partially, to answer these questions, which have far-reaching implications.

METHOD AND SCOPE OF STUDY

The basic data for the study upon which this report is based, were obtained by personal interviews with representative sugar-beet growers in Monterey and Yolo Counties. Each of these counties is the center of beet production in its respective area. Yolo County was selected to represent the Sacramento Valley, and Monterey County to represent the central coast counties. Information was obtained from growers on the amount and cost of labor, tractor work, and materials used in producing the 1947 beet crop, and in harvesting it, whether by hand or by machine. Some growers selected at random outside the original sample were interviewed to provide a sufficient sample of mechanical harvesters.

The survey of mechanical harvesting was repeated in the 1948 season. The farm survey included 31 records of beet-production data in Yolo County and 46 in Monterey; it included operation records of 26 two-row spike-wheel harvesters and 16 one-row hand-sorting harvesters. Data relating to acreage, production, and sugar content of beets were supplied by county Agricultural Conservation Associations, which administer the program under the Sugar Act.

ECONOMIC EFFECTS OF HARVEST MECHANIZATION

The mature sugar beet has a fleshy rootstalk and thick leaves growing out of the crown. Harvesting consists of digging, topping, and loading the roots into trucks for hauling to a sugar-refining plant. In the hand method of harvesting, the beets are first loosened by a subsoiler, with beet wing attachments, pulled by a tractor. This operation is called "lifting." Then crews of 8 to 15 workers "pull" the loosened beets, remove the tops (crown and leaves) with a beet knife, and pile or windrow the beets for subsequent hand loading into trucks (figs. 1 and 2). In mechanical harvesting the entire job is performed in one operation by a crew of one to three men who operate a machine pulled by or mounted on a tractor.

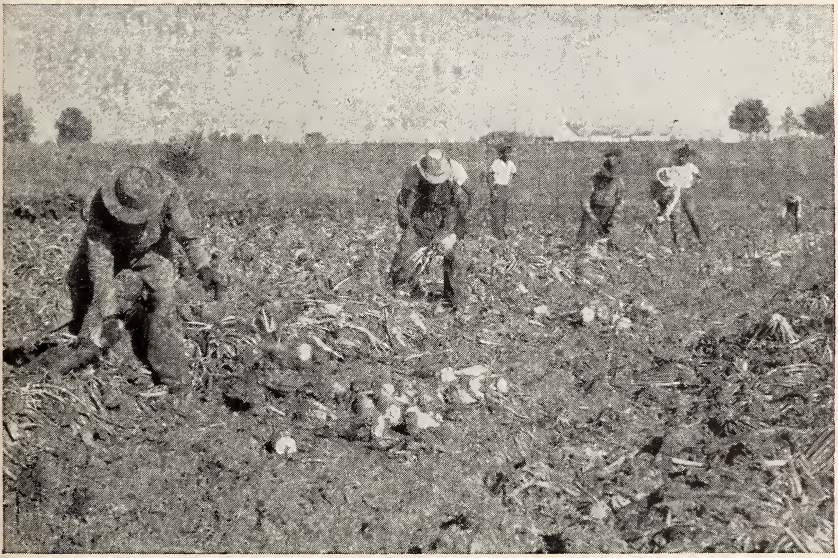

FIGURE 1.—Hand pulling and topping of sugar beets for subsequent loading into trucks. This laborious operation (plus loading) takes about 28 man-hours per acre when the yield is 17 tons. These beets were first "lifted" with a tractor and subsoiler with beet wing attachments.

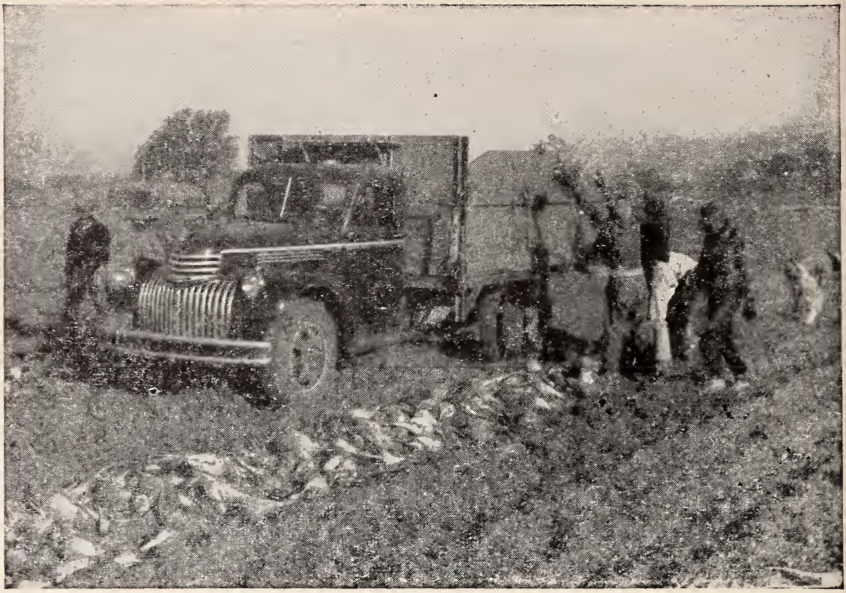

FIGURE 2.—After they have pulled and topped the beets, workers load them by hand into trucks.

EFFECTS ON INVESTMENT, LABOR REQUIREMENTS, AND COST OF HARVESTING[3]

Mechanization of a production operation normally means substituting mechanical power for human labor. This requires a larger investment in equipment and a smaller input of labor. For comparison with hand methods, the average investment in equipment, labor requirement, and cost of harvesting with two types of harvesters were estimated.[4] These estimates represent survey data adjusted to a harvester-depreciation schedule of 10 years, a representative yield of 17 tons per acre, and a seasonal use of 250 acres of beets with two-row harvesters and 125 acres with one-row machines.[5] Investment and cost are based on the 1948-49 price level; both would be somewhat higher in 1952. The differences in costs of harvesting between the two machines are not necessarily significant because only one was used in one of the areas studied, and because the estimates were based partly on judgment as to rates of depreciation and service life. As the two machines are designed for operations of different sizes, considerations other than cost are important.

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[3] Only the salient facts concerning investment, labor, and costs are presented in this section. A later section discusses in more detail the individual items of cost, how they were derived, and the variations arising from differing situations. (See section beginning p. 16.)

[4] A description of the two-row harvester is found on page 17 and of the one-row harvester on page 31.

[5] Seventeen tons is approximately the 6-year (1945–50) average yield of sugar beets in California. The depreciation schedules and seasonal capabilities are those deemed reasonable from the experience and evidence available.

HAND METHODS

Labor required per acre in hand harvesting includes about 1.4 man-hours in lifting and 28.1 man-hours in topping and loading, or a total of 29.5 man-hours (table 3). The amount of labor for topping and loading varies with the yield, though not in direct proportion (table 13). The investment in power and equipment averages (1948–49) $12.80 per acre. The necessary charge for power and machine use is $2.40, and the cost of labor is $37.27, making a total cost of $39.67 per acre in hand harvesting.[6]

TWO-ROW SPIKE-WHEEL BEET HARVESTERS

This study shows that with a two-row mechanical harvester the investment in power and equipment is larger ($36.00 versus $12.80) and the labor requirement is smaller (5.4 versus 29.5 man-hours) than with hand harvesting (table 3). Thus, in machine harvesting the necessary charge for power and machine use per acre is higher ($7.97 versus $2.40), and the cost of labor per acre is lower ($5.76 versus $37.27) than in hand harvesting. The saving in cost of labor more than offsets the additional costs of power and machine. Therefore, when a two-row harvester is used at reasonably full capacity, the total cost of harvesting (excluding hauling to factory or dump) is an estimated $13.73 per acre, which represents a saving of $25.94, compared to hand harvesting (fig. 3).

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[6] Further details on these costs are shown in table 7.

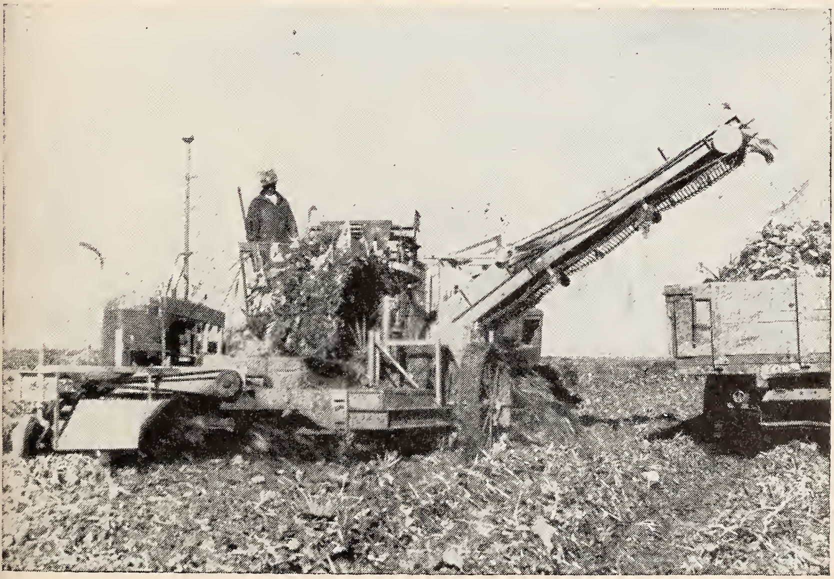

Figure 3.—A two-row spike-wheeled harvester lifts, tops, and loads the beets in one operation. The saving over hand harvest amounts to about 24 man-hours of labor, about $26 in total harvesting cost, per acre.

TABLE 3.—*Estimated investment, labor and cost of harvesting sugar beets by mechanical versus manual methods* [1]

Item	Unit	Hand harvest [2]		With 1-row mechanical harvester [3]		With 2-row mechanical harvester [4]	
		Total	Average per acre	Total	Average per acre	Total	Average per acre
Acres harvested annually [5]	Acre	125		125		250	
Investment in equipment:							
Harvester	Dollar	300	4.00	2,500	20.00	6,000	24.00
Tractor (beet share) [6]	do	1,100	8.80	1,100	8.80	3,000	12.00
Total	do	1,400	12.80	3,600	28.80	9,000	36.00
Labor requirements:							
Regular workers	Man-hour	175	1.4	1,225	9.8	1,350	5.4
Contract workers	do	3,512	28.1	----	----	----	----
Total	do	3,687	29.5	1,225	9.8	1,350	5.4
Cost:							
Tractor [7]	Dollar	259	2.08	295	2.35	686	2.74
Harvester [7]	do	40	.32	642	5.24	1,304	5.23
Labor	do	4,658	37.27	1,325	10.60	1,440	5.76
Total	do	4,957	39.67	2,262	18.19	3,430	13.73

[1] Cost of harvesting in this table does not take into account the lower value of beet tops resulting from machine harvesting. Investments and costs are calculated at 1948–49 price level adjusted to reasonably full seasonal use of mechanical harvesters and average yield of 17 tons per acre. Cost of hauling beets to factory or dump is not included.

[2] Beets lifted with 25–30 HP tractor and 2-row beet lifter, and topped and loaded by hand.

[3] Beets harvested with 1-row, hand-sorting beet harvester mounted on 26 HP general-purpose tractor, with two apron men used two-thirds of the harvest season.

[4] Beets harvested with 2-row spike-wheel beet harvester and 50–60 HP tractor; one hand gleaner used full time.

[5] Assumed to be reasonably full seasonal capacity.

[6] Beet-harvest share is assumed to be 20 percent of the lifter tractor; 44 percent of the "1-row" tractor; 37.5 percent of the "2-row" tractor.

[7] Including overhead items of imputed interest on investment, taxes, insurance, and shelter, as well as direct operating costs of fuel, lubricants, repairs, etc.

These are the costs (including overhead) of the harvesting operation, with the beets loaded into trucks at the farm. In addition to the harvesting cost, the quality of machine harvesting as compared to hand harvesting must be considered. Does the machine harvester recover all the beets, or at least as many as hand toppers do? What is the effect, if any, on value of beet tops?

Evidence available indicates that two-row harvesters are approximately equal to hand harvesting in recovery of beets.[7] Most of the growers interviewed were of this opinion. Sugar companies have noticed no reduction in yields since the growth of machine harvesting. Finally, groups of machine-and hand-harvested fields show no significant differences in yields of sugar.[8]

The possible effect of machine harvesting on the value of beet tops is important to the grower. Tops are valued as livestock feed and, as such, are a source of supplementary income. Evidence indicates that there is some waste of tops with the two-row machine because some are covered with soil or crushed by wheels of equipment or trucks. In 1947 cattlemen offered an average of $3.40 less per acre for the right to pasture beet tops on machine-harvested fields than for hand-harvested fields. Since 1947, a mechanical attachment to windrow tops has been devised in an effort to reduce loss and damage. Damage to tops may be diminishing, but the exact effect has been difficult to measure because growers have been more concerned with operating costs and with "turn-out" of beets.

To summarize, the economic costs of harvesting sugar beets with the two-row harvester include $13.73 per acre for the harvest operation and $3.40 for value of beet tops wasted, making a total cost of $17.13 per acre (1948–49). This sum subtracted from the cost of hand harvesting ($39.67 per acre) leaves a net saving of $22.54 per acre for machine harvesting. In 17-ton beets, a typical yield, the saving amounts to $1.32 per ton. Many growers stress an advantage that is not readily measured in economic terms. Mechanical harvesting frees them from a bothersome labor problem, that of having to secure hand-topping crews which, to their minds, are often undependable. Growers now can harvest the beet crop with regular farm labor, on a planned schedule.

ONE-ROW HAND-SORTING HARVESTERS

Harvesting costs with one-row hand-sorting harvesters, used on 125 acres annually amount to $18.19 an acre—$10.60 for labor and $7.59 for power and machine (table 3). Total labor required with this harvester is 9.8 man-hours per acre, one-third of the labor (29.5 man-hours) required in hand harvesting. Initial investment in harvesting equipment (including beet share of tractor) amounted to $3,600 with the one-row harvester compared to $1,400 with hand harvesting.

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[7] This question is discussed more fully in a later section, page 22.

[8] Some readers may question our measuring efficiency of mechanical harvesters by comparison with hand work. Some may think efficiency should be measured as a percentage of beets recovered. However, percentage of recovery is actually a measure of mechanical rather than economic efficiency. The economic question of concern to beet growers is how does efficiency of available machine harvesters compare with efficiency of hand harvesting—the only alternative method available.

Evidence thus far appears to show that one-row, hand-sorting harvesters are equivalent to hand harvesting in field efficiency or recovery of beets. The effect on value or waste of tops is not well established. From the study made, it appears that harvesting with this machine does not reduce the value of beet tops to any appreciable extent because the beet trucks do not follow the machine over the field; also, because the windrowing device has been improved.

Digging sugar beets with a one-row harvester used at reasonably full capacity results in a saving of $21.48, or $1.26 per ton, compared to hand harvesting (fig. 4).

EFFECTS ON OTHER PRODUCTION COSTS

A new harvesting machine may require costly changes in other production operations and therefore may dissipate some of the initial savings it brings about. In mechanizing the harvesting of sugar beets neither additional nor more expensive operations are required of operators who have suitable tractors. Methods of planting, row spacing, and cultivation required for optimum production are adapted to machine harvesting. Normal weed control, consistent with optimum yields and efficient production, is also adequate for mechanical harvesting.[9] Savings in machine harvesting, therefore, are generally reflected in lower costs of production. In 1948, when both yield and sugar content were below average, mechanization of harvesting meant the difference between profit and loss to many growers in Monterey County.

EFFECTS ON ORGANIZATION AND OPERATION OF FARMS

Mechanization of harvesting has increased relatively the net returns in producing sugar beets; that is, beets now are a more profitable crop than they were when harvested by hand. Also, the profit position of beets has been raised in relation to other crops. This changed economic situation suggests the possibility of a shift in acreage from other crops into beets, in both the concentrated and the sparse areas of beet production. Existing growers might be expected to plant more beets. New growers and new areas might be expected to enter beet production. Changes in the organization and operation of farms thus affected might also be expected.

But individually, farmers will react to the new situation in various ways. Farmers often select crops for reasons other than high returns—to insure better rotations and help soil conservation, to spread price risk and labor load, and for many other reasons.

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[9] It is true that operation of beet harvesters is hindered by weedy conditions, but weeds also hamper hand harvesting. A discussion of adaptability of harvesters to weedy conditions and requirements for successful machine operation is found in a later section (p. 20).

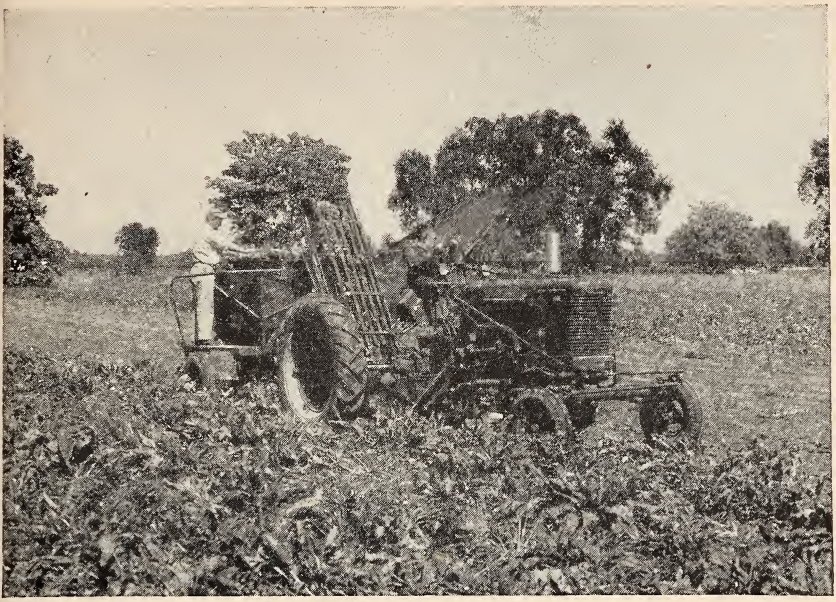

FIGURE 4.—One-row hand-sorting harvester in operation in a field near Woodland, Yolo County. This machine tops and lifts the beets and carries them up to a belt table where men sort out the clods. The beets accumulate in a trailer bin for subsequent transfer to a truck.

Thus, a farmer often produces a variety of crops which yield widely different net returns per acre. Sometimes a crop must become a great deal more profitable before it attracts any great shift in acreage.

The situation in concentrated areas of beet production may be illustrated by that of Yolo and Monterey Counties. In these areas farmers are already planting as large a beet acreage as good rotations will safely permit. Because of disease and insects, growers and landlords generally feel it unwise to grow beets on the same land, more often than every third or fourth year. This means that only 25 to 33 percent of the cropland is in beets each year. In 1947, survey growers in Yolo County had 20 percent of their suitable land in beets. For Yolo County as a whole the situation in recent years may be summarized as follows:

Year	*Acres of beets planted*	*Percentage of suitable land in beets*
1947	20,170	20
1948	31,594	31
1949	32,621	32
1950	33,578	33

The 1948–50 acreage of beets, despite mechanization of harvesting, was no greater than the 1940 acreage of 32,758 when harvesting was done entirely by hand. These data suggest that the 1948–50 acreage of beets was about equal to the practicable maximum limit.

The situation in Monterey County is much the same; in 1947 interviewed growers there had 32 percent of their available land in beets. For Monterey County as a whole the situation in recent years may be summed up:

Year	*Acres of beets planted*	*Percentage of suitable land in beets*
1947	31,228	32
1948	24,572	25
1949	14,813	15
1950	23,964	24

The acreage of beets has ranged between 15 and 32 percent of the available land. Fluctuations in acreage reflect the economic competition of lettuce, carrots, and other vegetable crops that are important in the county. These data suggest that mechanization of the beet harvest has not upset the pattern of farm organization and crops.

In less concentrated areas of production, the common rotations could safely include more acres of beets. Often, however, other obstacles limit expansion of acreage. These may include shortage of irrigation water, unsuitable soils, more profitable alternative crops, or limited capacity of sugar refineries. Because these other areas have not been studied in detail, only general comments can be offered. When the shift is from another summer-irrigated crop, water usually is not an obstacle in areas of pump irrigation, because beets are only moderate users of water. Beets produce satisfactory yields in other parts of the Sacramento Valley and in the San Joaquin Valley. This indicates that there are soils suitable for expanded production in areas not studied. Growers in the upper San Joaquin Valley at times have shown an interest in beets as an alternative to cotton. In that area mechanical harvesting would encourage beet growing because warm fall weather makes quick harvesting a necessity. However, during the first 5 years after mechanization of harvesting, the acreage of beets did not expand in that area. Cotton was more profitable.[10]

To summarize, mechanization of harvesting has stimulated no materially expanded acreage in California, either in areas of concentration or in those of scattered production. Perhaps mechanization has been only a method of maintaining existing acreage in competition with other crops. Certainly, the beet industry is stronger than it was before mechanization, and better able to survive periods of labor shortage such as occur in time of war.

OPPORTUNITIES FOR FURTHER MECHANIZATION IN PRODUCTION OF SUGAR BEETS

Opportunities for further mechanization in beet production are found in thinning, hoeing, and weeding—operations still performed with the simplest hand tool, the short-handled hoe. These operations still require about 28 man-hours, (17 in thinning and 11 in hoeing and weeding) which is more than half the 50 hours required in producing an acre of beets with the harvest mechanized.

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[10] From 1946 to 1950 the total acreage of beets in six cotton counties fluctuated between 10,000 and 25,000 acres; the acreage of cotton ranged between 500,000 and 1,000,000 acres. See table 19 for trends in beet acreage by areas in California.

THINNING

Why has thinning by hand persisted despite strenuous efforts to mechanize beet production? The answer to this question cannot be found in the purely mechanical field. Planters are available that will space single seed pieces evenly in the row and at uniform depth. Machines that will cut uniform blocks of any width and interval desired are available. Obstacles to successful mechanical thinning lie in the cultural requirements and the perversity of the sugar beet plant itself. These are:

1. Frequent difficulty of getting uniform seedling emergence owing to the crusting of the soil and adverse weather.
2. Too high a percentage of multiple and double plants, even though processed seed is used.
3. Necessity of a highly uniform final stand to obtain maximum yields.

For these reasons many growers continue to plant more seed than would otherwise be needed. Therefore, they have a major job in reducing the stand. The uneven thick stands that result are difficult to thin mechanically; the machine overthins some spots and underthins others.

The serious effect of stand on yield and income needs further comment. Few other field crops are so critical in this respect. Many experiments show that there is a marked reduction in yield from crowding (multiples) and from skips (row spaces with no plants). In 1950 each ton so lost from the potential yield represented roughly $10.75 less income to the average grower in California.[11] The loss from 1.5 tons of beets per acre would have been more than the cost of hand thinning (about $14.50 per acre).

Research and experimentation are being carried on along three major lines: (1) To develop a seed piece with single germinating cell; (2) to overcome the hazards of seedling emergence, and (3) to devise methods of using existing machines to thin more satisfactorily the usual nonuniform stand. These specific studies are not discussed here but considerable progress has been made along each of these lines.

Development of a single germ seed will not solve the thinning problem unless uniform emergence can be assured. Heavy plantings would have to be continued and the resulting stands reduced. If and when the problem of seedling emergence is solved, hand work can be held to a minimum. A grower can plant to a stand—a uniform light planting that requires no thinning, or only a light "touching up" with the hand hoe, perhaps combined with the first hoeing. This opportunity is now available to growers who obtain reasonably uniform seedling emergence. To the extent that processed seed is further improved, less touching up will be needed.

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[11] The $10.75 represents the average field value per ton of the 1950 crop. It is derived by subtracting a harvesting cost of $1.50 (custom rate) and a hauling cost of $1.00 from a gross return of $13.25 per ton ($10.90 factory payment and $2.35 Sugar Act payment). In these calculations no allowance is made for loss of beet tops and it is assumed that other production costs remain unchanged. Field value of hand-harvested beets was about $10.00 per ton. For the grower who used his own spike-wheel harvester at full capacity the field value was about $11.24 per ton ($13.25 minus $1.01 for harvesting and $1.00 for hauling).

A newer idea for using mechanical thinners on imperfect stands is called "random stand reduction" (fig. 5). Its objective is to eliminate hand work entirely. This system calls for no blocking such as cutting out all plants from intermittent segments of the row. Instead, the stand is thinned with a less vigorous tool in several operations (times over), each in a different direction across the field. Suggested tools are rotary hoes, finger weeders, side-delivery hay rakes, and similar machines. Among the advantages attributed to random stand-reduction are: It gives an opportunity to observe the results of each stage before continuing with the second or third time over, and reduces the likelihood of a "skippy stand" because of the random effect obtained from several light thinnings from different directions. Random stand reduction has not been an unqualified success. In some instances it leaves too many multiple plants.

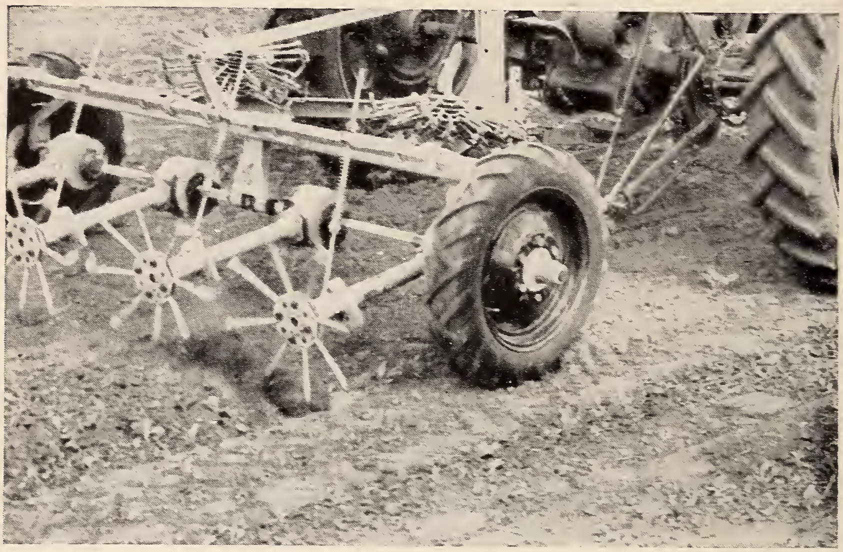
FIGURE 5.—One of the newer four-row machines used in random stand-reduction, to reduce the hand work in thinning sugar beets.

When seedling emergence is retarded because of soil crusting, heavy planting should be practiced. This system results in an excessively heavy population of plants. If skips in the row are not prevalent some form of mechanical down-the-row blocker, cross-blocker, or even cross cultivation may be used to reduce hand thinning. This device is advantageous if thinning has been delayed by the weather, as a large acreage can be covered quickly with a mechanical blocker. Removal of beet plants and weeds from the cut segments of the row relieves the remaining beet plants of some competition from weeds and plants.

WEED CONTROL

The average labor requirement for hand hoeing of beets is about 11 man-hours in Yolo County and 20 or more hours in Monterey County. The main purpose in hoeing is to control early spring weeds in the seedling stands, although, if the weeds get out of hand, later hoeings are sometimes needed. Where the beet plants are established, weeds ordinarily can be controlled by tractor cultivation, except the late summer weeds such as Johnson grass and "water grass." Hand hoeing may be reduced by pre-emergence spraying with chemical herbicides, and general improvement of cultivation practices from the standpoint of both technique and timing. Also, general farming practices could be improved, better rotations could be followed, and fences and banks of ditches could be kept free from weeds.

Information concerning pre-emergence spraying is contained in various publications of the California Agricultural Experiment Station at Davis. Results thus far obtained there show that pre-emergence spraying with herbicides is not effective under all conditions. But where it works, hand hoeing is largely eliminated as a labor and cost item. The saving to the grower is the difference between the cost of hoeing and the cost of spraying.

Research in improved cultivation has included: Methods of operating the sweeps closer to the plant row, shallower cultivation to avoid raising ungerminated weed seeds into the germinating zone, and methods of timing cultivation that will kill weeds when they are still small.

Probable Economic Effects of Further Mechanization

Since no proved machine methods of thinning and hoeing beets are available in California, their probable effect on labor requirements and costs in beet production cannot be measured precisely; only rough estimates can be made. These operations now require about 28 man-hours of labor—roughly 17 man-hours for thinning and 11 man-hours for hoeing—at a cost of about $24 an acre.

Whether hand thinning and hoeing will ever be eliminated entirely for all growers in California is doubtful. Certain seasons, particular fields, or particular soils may be unfavorable for mechanical operation. But many growers will doubtless be able to use a combination of mechanical thinning and a moderate amount of hand thinning. The hand work may resolve into a once-over operation of touching up the stand and hoeing. Estimates presented here, however, allow for one later hand hoeing.

From the Colorado studies and other experiments, it seems likely that hand thinning can be reduced, on an average, by about half.[12] The mechanical blocking operation would require about

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[12] See references in footnote to table 4.

0.6 man-hours and would cost about $1.20 per acre (using the rate of $2.00 per hour for similar operations). The hand touch-up operation might require about 9.0 man-hours per acre. In Yolo County, the net saving in labor would be about 7.9 man-hours, and the reduction in cost about $5.65 per acre. In Monterey County, where costs of hand thinning average higher, savings would be greater.

The probable economic effects of mechanized hoeing or weed control are also speculative. The more promising device, as previously mentioned, is pre-emergence spraying with chemical herbicides. The cost of spraying depends upon the kind and quantity of materials used and the method of application. Pre-emergence spray can be applied either by ground equipment or by plane. Recent figures on cost of spraying by plane place this at about $6 per acre.[13] Compared to the average cost of hand hoeing of $9.57 per acre in the Yolo area, the saving from pre-emergence spraying would be about $3.57 per acre. In Monterey County, where the cost of hand hoeing averages $20.15 per acre, the saving would be about $14.15 per acre. When pre-emergence spraying is not feasible, improved cultural practices could reduce the labor of hand hoeing to (say) 6.0 man-hours in Yolo County, a saving of 5.2 hours which represents $4.42 in costs.

To summarize, mechanizing the spring work of thinning and hoeing would probably reduce the labor requirement (excluding contract spraying) by about 12.5 man-hours and the cost of these operations by approximately $10 per acre. Whereas mechanization of harvesting has reduced the total labor required in producing beets from about 75 to 51 man-hours, mechanization of spring work will probably further reduce labor requirements to about 38 man-hours (table 4).

PERFORMANCE AND HARVESTING COSTS WITH MECHANICAL HARVESTERS

The two makes of mechanical harvesters studied are discussed in this publication. Both makes are once-over machines that lift, top, clean, and load the beets into trucks, but they are of widely different design. The machine that employs the principle of a spike wheel for lifting, comes in both one-row and two-row models which are pulled by tractors, and a one-row model which is tractor mounted.[14] The two-row model only was studied; the other models were not found in the two areas when the study was made. In the discussion this harvester is referred to as the "two-row spike-wheel harvester." The other machine is tractor-mounted, comes only in a one-row model, trails an elevator-bin cart for accumulating beets

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[13] Spreckels Sugar Beet Bulletin, Vol. 13, No. 6, p. 42, November–December, 1949, Sacramento, California.

[14] The one-row mounted machine came into commercial use after this study was made. Although detailed data are lacking, the cost of harvesting and the efficiency of this model are believed to be comparable with those of the two-row model. Almost 300 of the new machines were used in California during the 1951 season. A picture of this machine is shown in figure 7.

TABLE 4.—*Estimated labor required to produce and harvest an acre of sugar beets with various degrees of mechanization, Yolo County, California*

Operation	With neither spring work nor harvest mechanized [1]	With harvest mechanized	With both spring work and harvest mechanized [1]
	Man-hours	*Man-hours*	*Man-hours*
Plow, level, and prepare	3.5	3.5	3.5
Plant	.5	.5	.5
Cultivate and furrow	2.7	2.7	2.7
Hand block and thin	16.9	16.9	[2]9.0
Mechanical block and thin			.6
Hand hoe and weed	11.2	11.2	[3]6.0
Irrigate	10.5	10.5	10.5
Total to produce	45.3	45.3	32.8
Lift	1.4	(4)	(4)
Top and load	28.0	(4)	(4)
Machine harvest [5]		5.4	5.4
Total to harvest	29.4	5.4	5.4
Total labor required [5]	74.7	50.7	38.2
Labor saved by mechanization		24.0	36.5
Percentages reduction in labor		32	48.9

[1] Spring work includes blocking, thinning, hoeing, and hand weeding.

[2] Estimate based on studies in other areas of mechanical blocking and thinning. See MERVINE, E. M. and BARMINGTON, R. D. MECHANICAL THINNING OF SUGAR BEETS Bul. 476, March 1943, and SITLER, HARRY G. and BURDICK, R. T., THE ECONOMICS OF SUGAR BEET MECHANIZATION Bul. 411–A, April 1950, Colorado Agricultural Experiment Station, Fort Collins, Colo.

[3] Estimate based on use of pre-emergence spraying where feasible and a general improvement in cultivation and other weed-control practices. See text for assumptions.

[4] Assumes fields are not opened by hand harvest.

[5] Assumes use of 2-row harvester followed by one field hand gleaner. The 1-row harvester takes 9.8 man-hours, (17-ton yield) including 2 sorting men 2/3 of the harvest season.

or for direct truck loading, and employs the principles of hand sorting. It is referred to here as the "one-row hand-sorting harvester." This machine was found only in Yolo County.

TWO-ROW SPIKE-WHEEL HARVESTERS

DESCRIPTION

The most striking feature of the two-row spike-wheel harvester is a pair of wheels, 6 feet in diameter, fitted with closely spaced spikes on the rim (fig. 6). As the harvester moves along the row, plowlike tools loosen the beets and the spikes lift them from the ground. The beets pass over topping chisels or disks, are then wedged off the spikes, drop on cleaning rollers, and thence go to a conveyor belt which elevates them into a truck that moves beside the harvester. The tops are wedged off the wheel and fall to another conveyor belt which windrows them to one side. Some operators use a special extension to this conveyor on alternate rounds which permits the tops from two rounds to fall in one windrow more easily avoided by the trucks.

A 4-cylinder, gasoline auxiliary motor provides the power for the moving parts and hydraulic lift of the spike wheels of this harvester. This motor powers the regular equipment, the topping disks, sickle, cleaning rollers, and conveyors, and drives the defoliator attachment when used. The motor is controlled by a governor and the harvester mechanism operates at constant speed independent of ground speed. The defoliator is a horizontal cutting blade and propellor set to remove beet leaves, grass, and weeds from the next two rows and scatter them over the ground already harvested. Normally, the blade is set to leave from 6 to 10 inches of leaf on the beet.

Some operators have installed so-called ground drives for turning the spike wheel. As originally designed, the wheels were turned entirely by contact with the ground, but the necessary

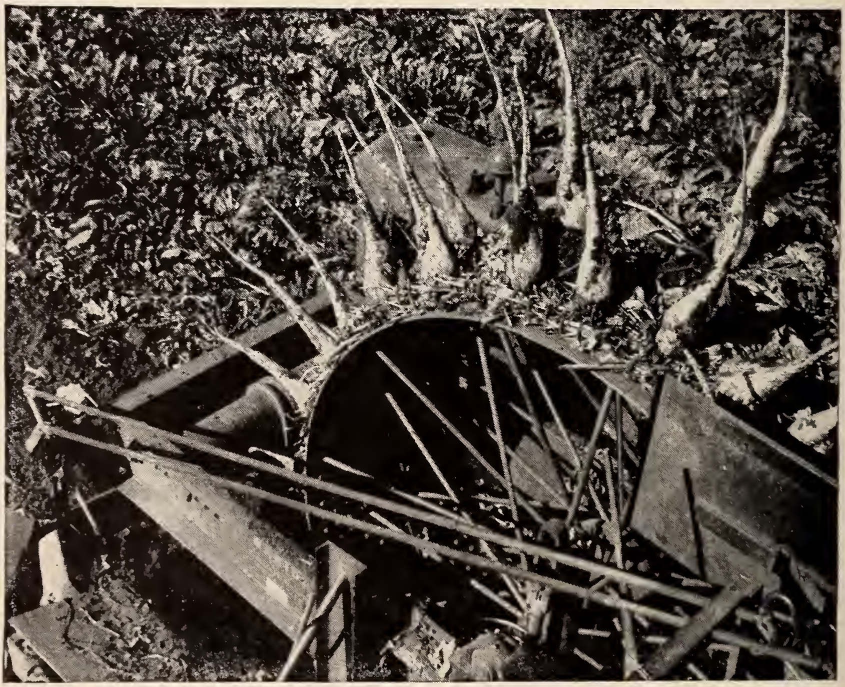

FIGURE 6.—Close-up view of two-row spike-wheel harvester showing beets impaled on the closely spaced spikes.

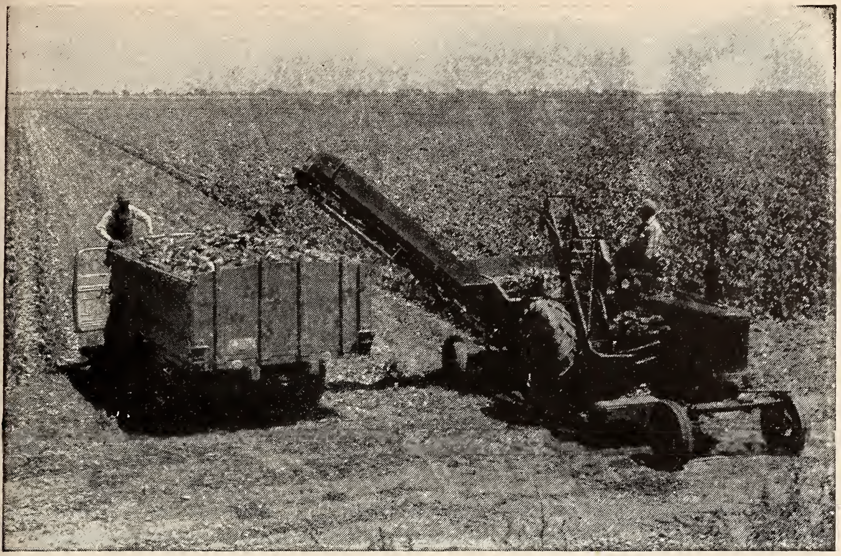

Figure 7.—One-row spike-wheel harvester transferring beets from trailer bin to beet truck standing at the edge of the field. This more recently developed machine was not studied.

pressure often made them push over or break off any large or protruding beets. The new ground-drive device uses a sprocket chain to connect the spike wheels to the bearing wheels of the harvester. The spike wheels can then be operated in a slightly higher position and can be synchronized with the forward speed of the machine. Thus excessive pressure is eliminated and the number of pushed-over and broken beets is reduced.

POWER AND CREW

This harvester requires a powerful track-laying tractor, the type common on medium to large beet-growing farms in California. With average beets and average soil a 50–60 horsepower tractor is adequate, but in hard ground or heavy stands of beets a larger 60–80 horsepower tractor is more satisfactory. The greater power speeds up field operations and the greater weight helps to hold the harvester on the row.

A minimum crew includes a harvester operator and a tractor driver, although some growers use one or two hand gleaners to recover beets missed or dropped by the machine (fig. 8). Because hauling is usually a contract job, truck drivers were not considered a part of the crew in this study. With average yields of 17 tons per acre and average hauls of 10 miles to the dump, three drivers with trucks are adequate.[15] Most growers use their best tractor driver and their most experienced employee, or foreman, for this work or operate the harvester themselves. Considerable skill is needed to operate a harvester efficiently and to keep it properly adjusted. Growers want the best men available and accordingly pay higher wages for this than for any other work.

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[15] Trucks rated at 2-ton capacity often haul from 5 to 7 tons of beets.

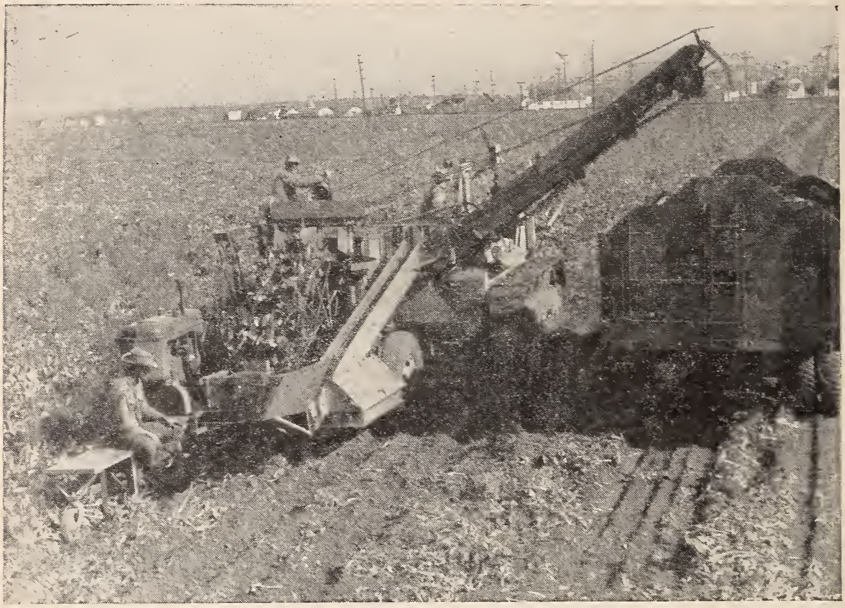

FIGURE 8.—Two-row spike-wheel harvester with a third man (gleaner) sitting on a rear platform recovering missed beets.

CAPACITY AND ADAPTABILITY

The capacity of sugar beet harvesters is important from several standpoints—output in acres, or tons per hour or day, output per season, and the internal capacity of the machine, that is, the ability to top, clean, and load all the beets it can dig. The basic capacity of any farm machine is amount of work done per hour; hourly performance can then be extended to output per day or season. The best measure of a beet harvester's capacity is acreage per hour (or day) rather than tonnage. Tonnage is affected by yield, and a harvester covers just about so much ground regardless of yield. Output in tonnage is important, however, in comparing mechanical with hand harvesting.

The acreage harvested per hour is closely related to ground speed and row spacing. In the areas studied, two beet rows usually occupy 40 inches of space. A machine with a 40-inch cut, traveling at 2.0 miles per hour, theoretically covers 0.8 acre in an hour; at 3.0 miles per hour it covers 1.2 acres in an hour.[16] But in practice, harvesters cannot equal these rates. Actual output is considerably reduced because of turning, stops for servicing, adjustments, and rest periods. On the average, the harvesters surveyed harvested 0.62 acre per machine-hour (table 15). Assuming a standard figure of 0.67 acre per hour, or 1.5 machine-hours per acre, this machine can harvest 6.0 acres and (with a 17-ton yield) 102 tons of beets in a 9-hour day.

Output per day depends upon the number of machine-hours worked. In the 1948 season, the harvesters surveyed were operated an average of 8.6 machine-hours per workday. This figure excluded time lost in major stoppages for repairs but included incidental service work and time for minor repairs and adjustments during the actual operating workday. As distinguished from the machine-day, harvesting crews worked an average of 10.1 hours a day. The extra time was consumed in morning and evening service work, repairs, and adjustments.[17] During the peak of the harvest season, machine-days averaged even shorter than 8.6 hours. Mechanization had so speeded up harvesting that sugar factories were unable to accept beets in the volume harvested, and so gave each grower a daily or weekly delivery quota. During the peak season most growers could harvest their quotas in 5 to 7 machine-hours. Late in the 1948 season, when individual quotas were increased (some growers had finished harvesting), the average machine-day increased to 10–12 hours, which as shown by experience, is about the maximum workday that can be maintained without undue fatigue to harvester crews. During short periods crews have worked a 15-hour day. The optimum machine-day for a crew is around 8 to 9 hours, with the crew working a full 10 hours.

The length of the harvester workday is flexible; there is nothing to prevent round-the-clock operation. Harvesters equipped with lights work as well at night as during the day. Except for the limitations of delivery quotas, growers could employ two crews and work night and day.

Length of the harvest season is best stated in terms of days available for work, rather than over-all length, which is about 75 to 90 days in the areas studied. Length of season depends upon the date that beets mature ready for harvest and upon weather conditions, particularly the onset of fall rains. The 18 harvesters studied were operated an average of 51 days (442 machine-hours) during the 1948 season, which began 2 or 4 weeks later than usual, be-

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[16] This harvester apparently has the capacity to operate at good normal tractor speeds. Some growers who used the larger tractors reported operation in third and fourth gears at speeds upward of 4 miles an hour. Other growers preferred slower speeds to avoid undue fatigue of the crews. Optimum speeds appear to be from 2 to 3 miles an hour.

[17] Crew time spent in *major* repairs was charged as maintenance labor and included in the item "maintenance and repair" in table 7; it is a part of the same item in table 16.

cause many fields had been replanted late and ripening was slow. The average beginning date among survey growers was September 5 (one began August 15) and the average finishing date was November 15 (one finished December 3). Growers in Yolo and Monterey Counties usually try to complete harvesting by November 15 to 30, since after that period seasonal rains often interfere with both machine and hand harvesting. Rain seriously hampered machine harvesting in the latter part of both the 1950 and 1951 seasons.

In view of all factors affecting daily and seasonal output, it seems reasonable to assume that a two-row spike-wheel harvester can be operated about 50 working days and can harvest about 250 acres in a typical season.

Two-row spike-wheel harvesters first gained grower acceptance in California because they could be operated in hard ground, a typical condition in many beet fields at harvest time. These harvesters are stopped by muddy fields because of their own weight, and the weight of tractors and trucks; however, operators claim that the new ground drives, described above, permit the harvesters to operate in somewhat wetter fields. These harvesters also apparently have the capacity to top, clean, and load all the beets they dig even in high-yielding fields.

HARVESTING EFFICIENCY

Harvesting efficiency, that is, the ability to recover all salable beet tissue, can be measured in either absolute or relative terms. Absolute efficiency is the ratio of actual recovery to total tonnage in the ground. Relative efficiency is the ratio of recovery by machine harvesting to recovery by hand harvesting. The grower who considers a shift to mechanical harvesting is primarily interested in relative efficiency. The grower who has made the shift is interested in improving machine efficiency to the extent to which it will pay.

Efficiency of machine harvesting in recovering beets may be affected in various ways. If the machine is not centered on the row, harvesters sometimes miss beets; although this loss can be minimized by careful operation. Hollow-crowned beets are sometimes missed or dropped after they are spiked. Faulty adjustment of the plow may cause the wheel to break off a beet and thus a salable taproot is lost. Beets may be lost by uneven or imperfect topping. Hand harvesting can also be inefficient, as hand toppers sometimes overlook beets, leave salable tissue on the crown, or lose beets in loading.[18]

From evidence available, two-row, spike-wheel beet harvesters apparently recover as much of the beet crop as is recovered by hand harvesting. Among representative Yolo County beet fields in 1947, hand-harvested fields yielded 48.2 hundredweight of sugar per acre, and machine-harvested fields 52.4 hundredweight per acre (table 5). The quality of soil and history of yield was similar on the two groups of fields (table 5). Although in the

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[18] The slower worker falls behind others in the crew and in trying to keep up, may overlook some beets. A careless tractor driver, in plowing beets for hand topping, sometimes gets off the row and misses beets.

TABLE 5.—*A comparison of hand-harvested and machine-harvested sugar-beet fields in terms of average soil quality, normal yields, and 1947 production, Monterey and Yolo Counties*

Item	Unit	Monterey County		Yolo County	
		Hand harvested	Machine harvested	Hand harvested	Machine harvested
Fields in sample	Number	52	50	26	18
Harvest results:					
Yield per acre	Ton	20.6	20.9	14.6	16.6
Sugar percentage	Percent	17.30	16.52	17.09	16.47
Sugar per acre	Hundredweight	67.4	65.3	48.2	52.4
Soil quality and previous production history:					
Soil-index rating [1]	Index	(2)	(2)	67	70
Normal yield [2]	Ton	18.8	19.1	12.8	13.2
Normal sugar percentage [3]	Percent	17.63	17.90	16.83	16.86
Normal sugar per acre [3]	Hundredweight	62.9	65.1	40.9	42.3
Fertilizer application, 1947 [4]	Pound	130	134	48	49

[1] The Storie Soil Grade Index Rating.

[2] Not available.

[3] In general an average of the previous 7 years on the farm as determined by Production and Marketing Administration in administering the Sugar Act.

[4] In pounds of nitrogen per acre as reported by growers in the survey.

cases studied, the machine-harvested fields yielded more sugar, the difference was not statistically significant. A similar comparison in Monterey County showed that machine-harvested fields yielded slightly less sugar than hand-harvested fields, but again the difference was not statistically significant. Comparisons were not made in 1948 because the growing season was unfavorable and yields were abnormally uneven.

It may be noted that the tonnage was higher on the machine-harvested fields. But, the percentage of sugar in the beets was higher on the hand-harvested fields. That result coincides with the experience frequently voiced by growers and with what reasonably might be expected. Machine-harvested beets are dug, hauled to the dump, and weighed while still fresh and high in moisture. In contrast, hand-harvested beets often lie in the field exposed to sun and wind for hours or days until they partially dehydrate. Therefore, if the machine recovered as many salable beets as hand harvesting, it would be reasonable to expect more weight but a lower percentage of sugar than with the hand-harvested beets. Growers in both counties indicated that machine-harvested beets yield from 1 to 2 tons *more* per acre but one percentage point *less* in sugar content.

In 1947 one Monterey County grower harvested eight beds of a field by hand and an adjacent eight beds by machine. On the machine-harvested beds, the yield was 22.0 tons per acre and the sugar content was 16.9 percent. On the hand-harvested beds, the yield was 18.8 tons and the sugar was 18.5 percent. Sugar per acre was 74.4 hundredweight on the machine-harvested area and 69.9 on the hand-harvested area.

Additional, though admittedly only general, indication of the efficiency of machine harvesting is the fact that, with conversion to mechanical harvesting during the last few years, area average yields have not been noticeably lowered.

Still another indication was the fact that hand gleaners were not always used behind machine harvesters. Gleaners recover some beets, and custom operators employ gleaners as a condition of the custom contract to harvest all the beets. But in 1948, custom operators often did not use gleaners when harvesting their own crop. They reported that the value of the recovered beets seldom paid the gleaners' wages.

To summarize, statistically significant proof is lacking that machine harvesting is either less or more efficient in recovery of beets than hand harvesting. But most machine operators believe that mechanical harvesting is at least equally efficient and some think it more efficient than hand harvesting.

EFFECT ON VALUE OF BEET TOPS

The effect of mechanical harvesters on value of beet tops is hard to measure, as much depends upon the skill of the crew and the truck driver. When harvesters first came into use a portion of the tops was obviously destroyed in harvesting. The tractor, the harvester wheels, or the truck wheels crushed some tops into the ground or they were covered by dirt as they were discharged from the harvester. In 1947, before special windrowing attachments came into general use, cattlemen discounted the value of machine-harvested tops. In Yolo County they paid about 65 cents a ton (beet yield) for the right to pasture hand-harvested fields and 45 cents to pasture machine-harvested fields.[19] The new windrowing attachment appears to reduce loss and destruction of tops, but information is not available to indicate whether this improvement is reflected in pasturage fees.

COSTS OF HARVESTING

Costs of mechanical harvesting include direct operating costs such as wages, fuel, oil, and repairs and also overhead costs such as depreciation, interest on investment, personal property taxes, insurance, and shelter. The cost estimates that follow were based on the 1948 harvester-survey data, adjusted to 1948–49 prices of equipment and supplies, with some adjustments in items for which survey data were judged abnormal. These cost estimates were based upon the assumption that a two-row harvester receives a reasonably full season's use on 250 acres, if it operates 50 working days and averages 7.5 hours a day. That assumption is reasonable because several machines in the survey harvested more than 300 acres each.[20]

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[19] The differential amounted to $3.40 per acre in beets yielding 17 tons.

LABOR AND MATERIAL REQUIREMENTS.—Harvester crew time is 1.8 hours per acre, or about 20 percent more than the machine time of 1.5 hours per acre (table 6). The extra time is for servicing, adjusting, and minor repairing of equipment. Total labor required is 5.4 man-hours per acre, equally divided among tractor driver, harvester operator, and one field gleaner. Estimates of

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[20] It is assumed that the life for the harvester will be 10 years although some operators think present machines will become obsolete before they are that old. Informed people say the machine is capable of harvesting more than 2,500 acres during its lifetime. Our estimate of total life is a compromise between possible time-depreciation and wear-depreciation.

TABLE 6.—*Estimated performance, labor, and materials in harvesting sugar beets with a two-row spike wheel harvester and 50–60 HP tractor* [1]

Item	Unit	Average per—			
		Season	Acre	Machine-hour	Ton
Acreage harvested	Acre	250	1.00	0.67	0.06
Beets harvested [2]	Ton	4,250	[3]17.00	11.33	1.00
Harvester-tractor hours [4]	Hour	375	1.50	1.00	.09
Labor:					
Tractor driver	do	450	1.80	1.20	.11
Harvester operator	do	450	1.80	1.20	.11
Gleaners [5]	do	450	1.80	1.20	.11
Total [6]	do	1,350	5.40	3.60	.32
Harvester:					
Fuel	Gallon	450	1.80	1.20	.11
Oil	Quart	49	.20	.13	.01
Grease	Pound	56	.22	.15	.01
Tractor:					
Fuel	Gallon	1,560	6.24	4.16	.37
Oil	Quart	112	.45	.30	.03
Grease	Pound	78	.32	.21	.02

[1] Based mainly on survey data, adjusted to average yields, and to full seasonal use of harvester on 250 acres of beets.
[2] Clean basis (on which grower is paid).
[3] California average yield, 1944–49, reported by California Crop and Livestock Reporting Service was 17.4 tons per acre.
[4] Includes normal stops for incidental service, adjustment, and repair not exceeding 15 minutes.
[5] Assumes 1 worker full time or 2, half time.
[6] Primarily operating; excludes major repairs and seasonal overhaul.

fuel, oil, and grease required for the harvester are approximate averages of survey data (table 15). Fuel and lubricants for the tractor are those required for track-laying tractors of 50 to 60 drawbar horsepower. Repair parts were not itemized with materials as there is no convenient common denominator, other than value, for recording them. Repairs, including parts, labor, and shop jobs are included as a cost item in table 7.

TABLE 7.—*Estimated cost of harvesting sugar beets with a two-row spike-wheel harvester and a 50–60 HP track-laying tractor*[1]

Item	Annual costs	Average cost per—		
		Acre	Machine hour	Ton[2]
	Dollars	*Dollars*	*Dollars*	*Cents*
Harvester costs:				
Maintenance and repair[3]	500	2.00	1.33	11.8
Fuel	85	.34	.23	2.0
Lubricants	15	.06	.04	.4
Taxes[4]	30	.12	.08	.7
Insurance[5]	22	.09	.06	.5
Shelter	5	.02	.01	.1
Depreciation[6]	500	2.00	1.33	11.8
Interest on investment[7]	150	.60	.40	3.5
Total	1,307	5.23	3.48	30.8
Tractor costs:				
Overhead (beet share)[8]	465	1.86	1.24	10.9
Fuel	180	.72	.48	4.2
Lubricants[9]	41	.16	.11	1.0
Total	686	2.74	1.83	16.1
Labor costs:				
Tractor driver	495	1.98	1.32	11.7
Harvester operator	540	2.16	1.44	12.7
Gleaners[10]	405	1.62	1.08	9.5
Total	1,440	5.76	3.84	33.9
Total harvesting cost	3,433	13.73	9.15	80.8

[1] Based on survey data, adjusted to 1948–49 price level, average yields, and annual use of harvester on 250 acres of beets.

[2] Assumes a yield of 17 tons per acre.

[3] Includes parts, hired shop work, farm shop work, and farm labor.

[4] Assumed at 1 percent of the average value during life.

[5] Assumed at 75 cents per $100 of average value during life.

[6] Original purchase price less ending value divided by 10 years equals annual depreciation.

[7] Assumed as 5 percent of the average value during life.

[8] Including maintenance and repairs, taxes, insurance, shelter, depreciation and interest on investment. Assumes tractor averages 44 percent of annual use on beet harvest.

[9] Includes oil-filter cartridges.

[10] Assumes 1 worker used full time or 2, half time.

HARVESTER COSTS.—Total cost of operating the harvester itself is estimated at $5.23 per acre, or $3.48 per machine-hour (table 7). The two largest items are maintenance-and-repair $2.00, and depreciation $2.00, with interest on investment at $0.60 an acre. Fuel, lubricants, property taxes, insurance, and shelter altogether amount to $0.63 an acre.

The maintenance and repair item includes parts purchased, hired shop work, farm shop work, and farm mechanic labor; it includes both annual overhaul and current repairs during the harvest season.[21] Although the cost of maintenance and repair of a two-row harvester appears high, it does not seem excessive when compared with other farm machines equipped with auxiliary motors. Harvesting beets is a power-consuming job. Machine breakage is a hazard of operating in the hard or cloddy ground that is frequently found in California beet fields. Sandy abrasive soils are destructive to both front and rear plows; and dust is a wear-contributing factor to all moving parts. No attempt is made here to estimate from the survey the average incidence of replacement of various parts. Operators mention most frequently replacement of sickle bars, wheel spikes, ledger plates, topping knives, and hardening and resharpening plowshares and points. Less frequent replacements include bearings, V-belts, castings, and conveyor links or belts. The estimated cost of maintenance and repairs is somewhat below that found in the 1948 survey and above that in the 1947 survey. This item was judged abnormally high in 1948 because most machines had been operated for 2 to 3 years, just long enough to need major repairs.

Fuel consumed by the auxiliary motor averages 1.2 gallons and costs $0.23 per machine-hour (table 7). Harvesters equipped with defoliators take slightly more power and use more gasoline. Consumption of cylinder oil varies with operating conditions, the schedule for draining and refilling, and the condition of the harvester motor. Consumption of grease is nominal, as the harvester is equipped in most places with prelubricated bearings.

Depreciation is another big item in the cost of operating harvesters. This is a cost that "matures" when the grower replaces an old harvester with a new one. Total depreciation on a harvester is estimated and then allocated to convenient units of time or work, such as the year, hour, or acre. Total depreciation during the life of the machine equals original cost ($5,500) minus probable ending or salvage value ($500). If the harvester is kept 10 years, harvests 2,500 acres, and is operated 3,750 hours, the average depreciation is $500 per year, $2.00 per acre, or $1.33 per machine-hour (table 7). The effect of acreage harvested annually on depreciation and other costs is discussed in a later section.

Investment in the harvester is part of the cost of operation. If a grower obtains a loan to buy a harvester, the mortgage interest he pays is easily seen as a cost. Investment is a cost even when the grower pays cash for his harvester, because then his own money is "sunk" in equipment when otherwise it could be invested in stocks or bonds, and be earning dividends or interest. The average annual cost of investment is expressed by the term "interest on average investment." It is estimated by assuming an interest rate of 5 percent on \$3,000 (½($5,500+500)) or \$150, as an average annual charge. The charge is \$0.60 per acre or \$0.40 per machine hour.[22]

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[21] Ordinary daily service labor is combined with operating labor under another heading.

TRACTOR COSTS.—Estimated annual (beet share) and per acre costs of operating tractors used to pull two-row spike-wheel harvesters are found in table 7. Total cost of operating a tractor is \$2.74 per acre, or \$1.83 per machine-hour. The largest item is overhead, which includes maintenance and repairs as well as the usual items of depreciation, interest on investment, taxes, insurance, and shelter. Overhead was first figured on an annual basis, then the share chargeable to the beet harvest was estimated. The fuel charge includes both starting fuel when applicable and operating fuel. The per hour cost of fuel, cylinder oil, gear grease, and other lubricants (also oil-filter cartridges) was taken directly from survey data.

LABOR COSTS.—The tractor driver, harvester operator, and gleaners, who comprise the crew, usually work 10-hour full days or 5-hour half days and are paid wages accordingly. Estimated average wages of tractor drivers in harvesting crews are \$1.10 per hour, of machine operators \$1.20, and of gleaners \$0.90 per hour.[23] Thus total costs of labor average \$5.76 per acre and \$3.84 per machine-hour when one gleaner is used. The costs vary with the amount of gleaning labor used.

EFFECT OF ACREAGE HARVESTED ON COSTS

In the preceding section, an estimate is given of the costs of mechanical harvesting on 250 acres of beets, assuming reasonably full annual use of a harvester. More than 250 acres can be harvested by using two crews and operating both night and day. But many growers have far less than 250 acres of beets to harvest. So, the practical economic questions that arise are: How does amount of annual machine use affect harvesting costs per acre and per ton? Does it pay to maximize annual use? What minimum acreage justifies conversion from hand to machine harvesting?

Costs of mechanical harvesting include both overhead and operating costs. Overhead is a fixed annual charge, hence the cost of overhead per acre is high if the acreage harvested annually is small. In contrast, operating costs per acre remain relatively constant whatever acreage is harvested annually. Operating costs include wages of the crew, use of the tractor, and direct costs of operating the harvester, as follows:

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[22] Growers who question why they cannot use interest on investment as a deduction for personal income-tax purposes should be reminded that if they include it as an expense they must also include it as an income.

[23] These wage rates are somewhat higher than those for other farm work. Growers have found that it pays to employ skilled and capable crews because maintenance of equipment is better, harvester adjustments are more accurate and prompt, and output per machine-hour is greater. However, it is not imperative that crews be specialists in order to have satisfactory harvesting.

	Per acre
Operating costs of the harvester:	
Maintenance and repair	$ 2.00
Fuel (for harvester motor)	.34
Lubricants	.06
Total	2.40
Cost for use of the tractor[1]	2.74
Wages	5.76
Total operating cost	$10.90

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[1] Includes cost of overhead. Tractor overhead cost per acre does not vary with the acreage of beets harvested because it is assumed that the tractor would be used for other work if (or when) not harvesting beets. In the areas studied, beet harvesting competes with land preparation and other operations, for the use of tractors.

Overhead items on the harvester include taxes, insurance, shelter, interest on average investment, and depreciation. The first four items obviously are fixed annual charges, estimated as follows:

Taxes	$ 30
Insurance	22
Shelter	5
Interest on average investment	150
Total	$207

Depreciation on a harvester may be considered either as a fixed annual charge or a per acre charge, depending upon amount of annual use. The maximum practical service life of a harvester is assumed, in this study, to be 10 years, or 3,000 acres of harvesting. If a machine harvests 300 acres or less during a season, depreciation is a fixed annual charge of $500 ($5,500 — $500 ÷ 10 years). If it harvests more than 300 acres a season, depreciation is $1.67 per acre ($5,500 — $500 ÷ 3,000 acres) (table 8). If only 100 acres are harvested during a season the depreciation charge is $5 an acre. It is $2.50 an acre for 200 acres, $2.00 for 250 acres, and $1.67 if 300 acres or more are harvested.

The effect of annual use on cost of depreciation, overhead costs, and total harvesting cost per acre are shown in table 8 and figure 9. Note that total harvesting cost per acre is only sightly lower when the acreage harvested annually goes beyond 250 acres; the figures are $13.73 per acre on 250 acres, $13.16 on 350 acres, and $13.03 on 450 acres. Note also that harvesting costs per acre rise substantially when acreage harvested annually falls below 250 acres. For example, harvesting costs are $17.97 per acre on 100 acres and $25.04 on 50 acres. Although $25.04 is lower than the cost of hand harvesting, which is around $39 per acre, 50 acres is the approximate minimum for which it pays a grower to own a two-row harvester. On smaller acreages, custom harvesting or a smaller machine becomes more advantageous.

TABLE 8.—*Relationship of harvester depreciation, fixed costs, operating costs and total harvesting costs to acreage of beets harvested annually, with a two-row spike-wheel harvester* [1]

Acreage harvested per year	Harvester depreciation per year [2]	Fixed cost per acre			Harvester operating cost per acre	Total harvesting cost—	
		Depreciation	Other [3]	Total		Per acre [4]	Per ton [5]
50	$500	$10.00	$4.14	$14.14	$16.54	$25.04	$1.47
100	500	5.00	2.07	7.07	9.47	17.97	1.06
150	500	3.33	1.38	4.71	7.11	15.61	.92
200	500	2.50	1.04	3.54	5.94	14.44	.85
250	500	2.00	.83	2.83	5.23	13.73	.81
300	500	1.67	.69	2.36	4.76	13.26	.78
350	585	1.67	.59	2.26	4.66	13.16	.77
400	668	1.67	.52	2.19	4.59	13.09	.77
450	751	1.67	.46	2.13	4.53	13.03	.77
500	835	1.67	.41	2.08	4.48	12.98	.76

[1] Based mainly on survey data, adjusted to 1948–49 price level and average yields. A new harvester costs $5,500 and is assumed to have a salvage value of $500 at the end of its useful life. The assumed maximum length of service is 10 years, or 3,000 acres.

[2] Depreciation is $500 per year or $1.67 per acre, whichever is greater.

[3] Based on annual sum of (1) interest on investment, (2) taxes, (3) insurance, and (4) shelter, table 7.

[4] Harvester operating cost plus labor $5.76 and tractor cost $2.74.

[5] Assumes a yield of 17 tons per acre.

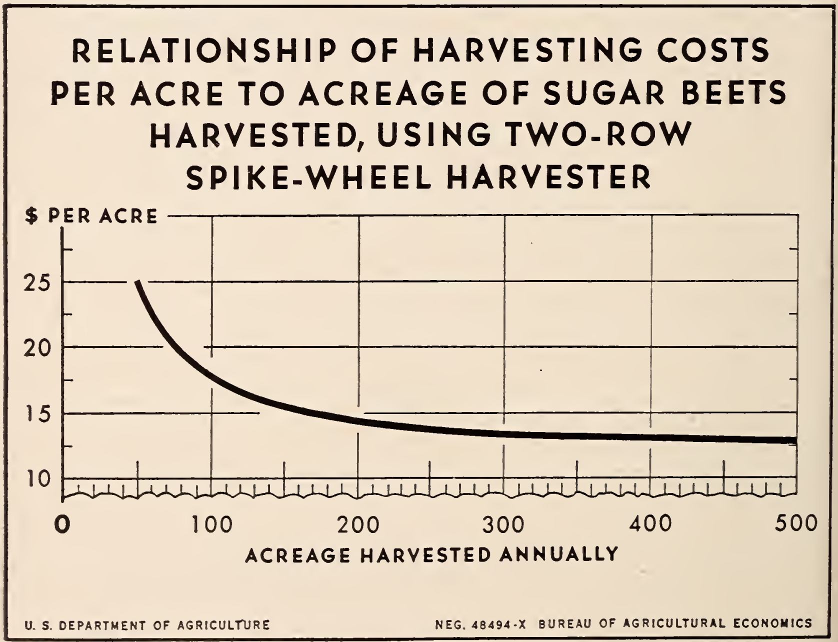

FIGURE 9.—Harvesting cost per acre with a two-row harvester increases sharply when the acreage harvested annually falls below 150 acres. They tend to level off when the annual acreage exceeds 250 acres.

ONE-ROW HAND-SORTING HARVESTERS

DESCRIPTION

These one-row hand-sorting harvesters are mounted on standard general-purpose tractors and trail loader-bin carts (fig. 10). The unit can be dismounted between seasons and the tractor can be used for other work. The harvester tops the beets before lifting them; topping is performed by a rotating scalloped disk, the depth of cut being regulated by a "finder." Rotating steel fingers pick the tops off the disk and throw them to one side against a canvas curtain, from which they drop to the ground in a windrow between the tractor wheels. A two-blade lifter raises the topped beets and guides them to cleaning rollers. The beets are then elevated to a sorting belt above the cart bin. One or two men stand on platforms beside this belt, sort out the beets into the bin, and allow the clods and trash to drop off the sorting belt to the ground.

Beets can either be accumulated in the bin and later transferred to a truck, or they can be loaded directly into a truck that moves beside the harvester. Most of the operators surveyed unloaded into a truck that stood at the end of the field. Unloading a full bin takes about one minute. As it takes three or four binloads to make one truckload, the driver can deliver one truckload to the beet dump while the harvester is digging and loading another truck.[24]

POWER AND CREW

Two sizes of tractors are available for mounting these harvesters; the smaller has a 20-horsepower gasoline engine and the larger has a 25-horsepower Diesel (or gasoline) engine. Under California conditions the larger tractor is considered more practicable and almost as economical to operate, although the original cost is higher. The larger tractor will operate the harvester in second gear in those soil conditions or with heavy yields under which the smaller tractor would have to operate in first gear. With one exception, the surveyed harvesters were mounted on the larger tractors.

The crew consists of a driver-operator and one or two sorters when the sorting belt is used to remove clods or trash; two men are used in heavy yields and one man in light yields. In the absence of clods and trash, no sorters are required and the sorting belt can be removed, thus letting the beets fall directly into the bin. The harvester then becomes a one-man machine. Examples of all three situations were found in the 1948 survey. Averaging all conditions over the season, 6.0 man-hours of sorting labor and 4.3

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[24] A grower located near the factory used only one beet truck for hauling. The beets were unloaded from the harvester into a pile on smooth ground at the side of the field. The truck driver then loaded his truck from this pile using another tractor equipped with a hydraulic scoop. This system made it unnecessary to coordinate harvesting and hauling as closely as when the beets were transferred directly from car to beet truck, an important consideration when a truck may be delayed at the beet dump.

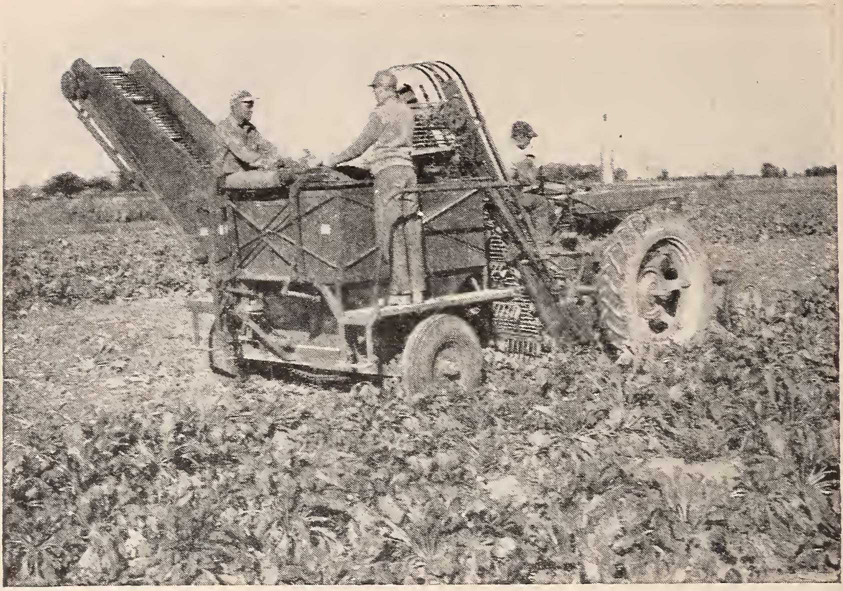

FIGURE 10.—One-row hand-sorting harvester in operation with two men at the sorting table. Under favorable conditions only one sorting man is used and sometimes none are needed.

hours of driver labor were used per acre—a ratio of 1.4 sorting to 1.0 driving. Apparently two sorters were used somewhat less than half the time. Growers can reduce the amount of sorting labor if they can minimize cloddiness by proper timing of irrigation. In the estimated costs that follow, it is assumed that 1.3 man-hours of sorting labor are needed on the average for each hour of operation.

CAPACITY AND ADAPTABILITY

The question to be answered under the heading "capacity and adaptability" is, How many beets can be harvested in an hour, a day, or an average season? The key measure of capacity is the acreage harvested per hour. This harvester operates at 2.2 miles per hour in first gear and 3.1 miles per hour in second.[25] Theoretically, in 20-inch rows it should cover 0.4 acre per hour in first gear and 0.62 acre in second. Because time was lost in turning, unloading, and incidental stops and because the harvesters surveyed were usually operated in first gear, they averaged 0.28 acre per hour of operation. At that rate, in beets yielding 17 tons per acre, the machine harvests 2.52 acres or 42.8 tons in a 9-hour day.

During the 1948 season, the harvesters surveyed were operated an average of 7.1 machine-hours per day, excluding time lost in major stoppages for repairs. Because of delivery quotas, hours per day averaged much less during the peak season. Late in the season when quotas were lifted the machine-day averaged up to 10 to 12 hours. Experience shows that during extended periods, machine-days of 7 to 8 hours and crew-days of 9 to 10 hours are the maximum without undue fatigue to the crews.

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[25] As stated in the operating manual furnished with the harvester.

During the 1948 season, in Yolo County, the harvesters operated an average of 44 working days, or 314 machine-hours, on 86.8 acres of beets. Machine use varied from as low as 17 days on 30 acres by one machine to 77 days on 152 acres by another. Five machines harvesting more than 100 acres averaged 130 acres in 60 days of operation. The remaining machines did not operate at full seasonal capacity because the growers had fewer beets to harvest and did little or no custom work. Judging from the 1948 season, in beets yielding 17 tons per acre, a one-row hand-sorting harvester can be operated 55 working days and can harvest 125 acres, or 2,125 tons of beets, in an average season.

This harvester has shown considerable adaptability to hard ground and wet soil, although in the two seasons surveyed it was generally unnecessary to operate under extreme conditions. In 1948 more fields were grassy than usual, and some growers found it desirable to remove excessive weeds and top growth with roto-beaters. Excessive grass is a problem with any method of harvesting, machine or hand. This harvester appears to work equally well in large or small beets. Apparently, it has the capacity to top, clean, and load all the beets it can dig. In heavy-yielding beets of 25 tons and more, the tractor usually is operated in low gear so as not to overwork the hand sorters. In average beets and in average soil conditions, the tractor can be operated in second gear.

EFFICIENCY OF HARVESTERS

Efficiency (recovery) with this harvester appears to be comparable to hand harvesting if the harvester is properly adjusted, the driver keeps on the row, and the sorting men are careful. The machine digs both large and small beets and apparently drops very few beets once they are dug. None of the operators interviewed in the 1948 season used hand gleaners. Unfortunately no reliable data were available with which to compare turn-out on fields harvested by this machine with turn-out on fields harvested by hand in 1948. Because of an unfavorable season, the crop was too variable to base any reliance on turn-out as a measure of harvester efficiency.

EFFECT ON VALUE OF BEET TOPS

This harvester windrows the beet tops between the tractor and loader cart wheels. If the machine is properly adjusted and operated, the tops are not damaged to any great extent, as traffic over the field is very little greater than in hand harvest. Growers who were interviewed reported that damage to tops was inconsequential.

The cost estimates that follow were based on certain assumptions, for example, that the harvester receives reasonably full annual use on 125 acres of beets. It was assumed that the average service life of the harvester is 10 years and that during the "off season" the harvester unit is dismounted and the tractor used for other farm work. Accordingly, only a third of the annual overhead cost of the tractor was charged to beet harvesting.

LABOR AND MATERIAL REQUIREMENTS.—Harvester-operator time is estimated at 4.2 hours per acre, or 20 percent above the machine time of 3.5 hours per acre (table 9). Sorting labor is estimated at 5.6 man-hours per acre. This is equivalent to two sorters working two-thirds as much time as the harvester operator. Estimates of requirements for fuel, oil, and grease are approximate averages of survey data.

HARVESTER OPERATING COST.—Estimated costs of operating a one-row hand-sorting harvester are summarized in table 10. Total cost of operation is $654.25 per year, $5.24 per acre, and $1.50 per machine-hour. The largest two items of cost are maintenance

TABLE 9.—*Estimated performance, labor and materials in harvesting sugar beets with one-row hand-sorting harvester mounted on 25-HP tractor* [1]

Item	Unit	Season total	Average per—		
			Acre	Machine hour	Ton
Acreage harvested	Acre	125	1.0	0.29	0.06
Beets harvested [2]	Ton	2,125	[3]17.0	4.86	1.00
Harvester-tractor hours [4]	Hour	438	3.5	1.00	.20
Labor:					
Tractor driver	do	525	4.2	1.20	.25
Sorting men (2/3 time) [5]	do	700	5.6	1.60	.33
Total [6]	do	1,225	9.8	2.80	.58
Fuel [7]	Gallon	744	6.0	1.70	.35
Oil [7]	Quart	50	.4	.11	.02
Grease [7]	Pound	100	.8	.23	.05

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[1] Based on survey data, adjusted to average yields and to full seasonal use of harvester on 125 acres of beets.

[2] Clean basis (on which grower is paid).

[3] California average yield, 1944–49, reported by California Crop and Livestock Reporting Service was 17.4 tons per acre.

[4] Includes normal stops for incidental service, adjustment or repair not exceeding 15 minutes.

[5] Sorting men may not be needed at all or only one may be needed in favorable soil conditions.

[6] Primarily operating; excludes major repairs, season overhaul, mounting and dismounting time.

[7] For both harvester attachment and tractor.

and repair at $2.24 per acre and depreciation at $1.72. Next come interest on investment $0.61, cost of mounting and dismounting $0.36, taxes $0.13, insurance $0.10, lubricants $0.06, and shelter $0.02 per acre.

TABLE 10.—*Estimated cost of harvesting sugar beets with a 1-row hand-sorting harvester mounted on a 25-HP tractor* [1]

Item	Annual cost	Average cost per—		
		Acre	Machine-hour	Ton [2]
	Dollars	*Dollars*	*Dollars*	*Cents*
Harvester costs:				
Mount and dismount [3]	45.00	0.36	0.10	2.1
Maintenance and repairs [4]	280.00	2.24	.64	13.2
Lubricants	7.00	.06	.02	.3
Taxes	16.00	.13	.04	.8
Insurance	12.00	.10	.03	.6
Shelter [5]	3.00	.02	.01	.1
Depreciation [6]	215.00	1.72	.49	10.0
Interest on investment [7]	76.25	.61	.17	3.6
Total	654.25	5.24	1.50	30.7
Tractor costs:				
Overhead (beet share) [8]	160.00	1.28	.36	7.5
Fuel	122.50	.97	.28	5.8
Lubricants [9]	12.50	.10	.03	.6
Total	295.00	2.35	.67	13.9
Labor costs:				
Tractor driver	625.00	5.00	1.43	29.4
Sorting men (2/3 time) [10]	700.00	5.60	1.60	32.9
Total	1,325.00	10.60	3.03	62.3
Total cost	2,274.25	18.19	5.20	106.9

[1] Based on survey data, adjusted to average yields, to full seasonal use of harvester on 125 acres of beets, and to 1948–49 prices.

[2] Assumes a yield of 17 tons per acre.

[3] Mostly labor; assumes grower uses own labor estimated at 25 man-hours to mount and 15 man-hours to dismount.

[4] Includes parts, hired shop work, farm shop work, and farm labor.

[5] Assumed at $3.00 per year.

[6] Original purchase price less ending value divided by 10 years equals annual depreciation.

[7] Assumed as 5 percent of the average value during machine life.

[8] Including maintenance and repairs, taxes, insurance, shelter, depreciation, and interest on investment. Assumes tractors average 37.5 percent of annual use on beet harvest.

[9] Includes oil filter cartridges.

[10] Sorting men are not needed at all or only one is needed in most favorable soil conditions.

The maintenance and repair item includes parts purchased, hired shop work, farm shop work, and farm-mechanic labor. No attempt was made to itemize the parts most frequently replaced. However, operators mentioned topping disks, hardening and resharpening plowshares and points, and elevator chain links. The estimated cost of maintenance is somewhat lower than was reported by operators in 1948 (table 18) because several machines had been operated just long enough to require major repairs, the kind not recurring yearly.

Depreciation was calculated as the difference between the original cost and ending, or salvage value of the harvesting unit—$2,600 minus $450, or $2,150. If the harvester is kept 10 years, harvests 1,250 acres, and is operated 4,375 hours ,the depreciation is $215.00 per year, $1.72 per acre, or $0.49 per machine-hour. The effect of acreage harvested annually on depreciation and other costs is discussed in a later section.

Investment is a cost of operation. For "interest on average investment," an interest rate of 5 percent on $1,525 (½ ($2,600 + $450)), or $76.25 per year was assumed. The charge is $0.61 per acre or $0.17 per machine-hour.

Mounting the harvester on the tractor at the beginning of the harvesting season and dismounting at the end are costs if the tractor is to be used for other farm work. Operators reported an average of 25 man-hours for mounting and 15 man-hours for dismounting. Labor and small parts such as new gaskets make the two jobs total $45.

TRACTOR COSTS.—Estimated annual (beet share) and per-acre costs of operating tractors with the harvester average $2.35 per acre, or $0.67 per machine-hour. The largest item is overhead, which includes maintenance and repairs as well as the usual overhead items of depreciation, interest on investment, taxes, insurance, and shelter. Overhead was first calculated on an annual basis, then a one-third share was charged to the beet harvest. Cost of fuel (gasoline) was adapted from survey data on a per acre basis, as were the costs of cylinder oil, gear grease, and other lubricants (all adjusted to the 1949–50 price level).

LABOR COSTS.—Average wages of tractor drivers are estimated at about $1.20 per hour and of sorting men at $1.00 per hour. Thus total labor costs per acre are estimated to average $10.60 per acre, or $3.03 per machine-hour. When two sorting men are used, labor costs $13.40 per acre; when one sorter is used $9.20, and when no sorters are used $5.00 per acre. Wages used in these estimates are higher than for other farm work, but the work is more exacting and more fatiguing than many other jobs. Moreover, growers are willing to pay higher wages to engage competent crews.

EFFECT OF ACREAGE HARVESTED ON COSTS

Estimated harvesting costs presented ($18.19 per acre) assume reasonably full annual use of the one-row harvester—125 acres per season. A considerably larger acreage could be harvested by using a second crew and operating at night; however, many growers have less than 125 acres to harvest. Practical economic questions that occur are: What effect does amount of annual use have on harvesting costs per acre? Does it pay to maximize annual use? What minimum acreage justifies owning a harvester? These questions were analyzed in the same way as for the two-row harvester. (see page 29.)

Operating costs per acre, including wages, tractor power, and direct costs of operating the harvester unit remain relatively constant at $15.25 per acre, whatever acreage is harvested. Overhead costs include taxes, insurance, shelter, interest on average investment, cost of mounting and dismounting, and depreciation. The first five items obviously are fixed annual charges estimated at $152 per year. Depreciation is a fixed annual charge when small acreages are harvested or a per acre charge when large acreages are harvested.

Depreciation on the harvester was estimated on a service life of 10 years, or 1,750 acres of harvesting. If a machine harvests 175 acres or less in a season, depreciation is a fixed annual charge of $215 ($2,600 — $450 ÷ 10 years). If it harvests more than 175 acres in a season, depreciation is $1.23 per acre ($2,600 — $450 ÷ 1,750 acres). Depreciation is $8.60 per acre if only 25 acres are harvested, $4.30 on 50 acres, and $2.15 on 100 acres a season.

The effect of annual harvester use on depreciation cost, other fixed costs, and total harvesting cost per acre are shown in table 11.

TABLE 11.—*Relationship of harvester depreciation, fixed cost, operating cost and total harvesting cost to acreage of beets harvested annually, with a 1-row hand-sorting harvester* [1]

Acreage harvested per year	Harvester depreciation per year [2]	Fixed cost per acre			Harvester operating cost per acre [4]	Total harvesting cost—	
		Depreciation	Other [3]	Total		Per acre [5]	Per ton [6]
25	$215	$8.60	$6.08	$14.68	$16.98	$29.93	$1.76
50	215	4.30	3.04	7.34	9.64	22.59	1.33
75	215	2.87	2.03	4.90	7.20	20.15	1.18
100	215	2.15	1.52	3.67	5.97	18.92	1.11
125	215	1.72	1.22	2.94	5.24	18.19	1.07
150	215	1.43	1.01	2.44	4.74	17.69	1.04
175	215	1.23	.87	2.10	4.40	17.35	1.02
200	246	1.23	.76	1.99	4.29	17.24	1.01
225	277	1.23	.68	1.91	4.21	17.16	1.01
250	308	1.23	61	1.84	4.14	17.09	1.00

[1] A new harvester costs $2,600 and is assumed to have a salvage value of $450 at the end of its useful life. The assumed maximum length of service is 10 years, or 1,750 acres.

[2] Depreciation is $215 per year or $1.23 per acre, whichever is greater.

[3] Based on annual sum of interest on investment, taxes, insurance, shelter, and cost of mounting and dismounting harvester unit.

[4] Total fixed cost plus cost of repairs and lubricants.

[5] Harvester operating cost plus tractor power and labor costs.

[6] Assumes a yield of 17 tons per acre.

The total cost of harvesting is only slightly lower when acreage harvested annually goes beyond 125 acres; the figures are $17.69 on 150 acres and $17.24 on 200 acres (fig. 11). However, harvesting costs per acre rise substantially when the annual harvested acreage falls below 125 acres. For example, harvesting costs on 50 acres are $22.59 per acre and on 25 acres, $29.93 per acre. Although $29.93 is lower than the cost of hand harvesting (about $39 an acre) 25 acres is the minimum acreage for which it pays a grower to mechanize with a one-row mechanical harvester. For small acreages custom harvesting is more economical.

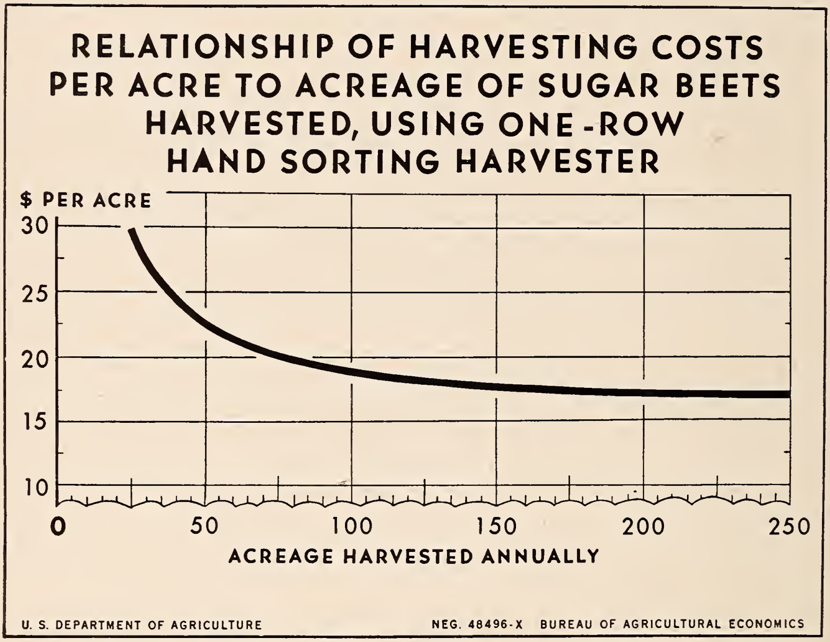

FIGURE 11.—Harvesting cost per acre with a one-row harvester increases sharply when the acreage harvested annually falls below 75 acres. They tend to level off when the annually harvested acreage exceeds 125 acres.

EFFECT OF YIELD PER ACRE ON HARVESTING COST PER TON

Hand workers can, in general, pull, top, and load more tons of high-yielding beets a day than low-yielding beets. Therefore, the wage per ton is customarily adjusted to the yield.[26] This chiefly explains why the cost per ton of hand harvesting in 1948 was $3.17 for yields of 10 tons per acre and $2.17 for yields of 20 tons (table 12). It also explains why cost *per acre* varies with the yield in hand harvesting.

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[26] Adjustments are made for yields up to 20 tons; for yields of 20 tons and above the same wage per ton is paid.

Mechanical harvesting cost per acre (excluding hauling) is relatively constant despite differences in yield, for yields within the usual commercial range. To find the cost per ton, divide the cost per acre by the yield per acre, in tons. This means that cost per ton is twice as large in 10-ton per acre beets as in 20-ton (table 12). It also means that the economic advantage of machine over hand harvesting increases as yield per acre increases. For example, the cost of machine harvesting 10-ton beets, (with a

TABLE 12.—*Cost per ton of harvesting sugar beets by hand and by machine, and usual charges for custom harvesting, at specified yields per acre, Monterey and Yolo Counties, 1948* [1]

Yield per acre (tons)	Hand harvesting [2]	Machine harvesting		Usual charge for machine custom harvesting [5]
		2-row machine [3]	1-row machine [4]	
6	$4.40	$2.49	$3.03	$2.85
7	3.94	2.16	2.60	2.58
8	3.61	1.92	2.27	2.39
9	3.36	1.72	2.02	2.25
10	3.17	1.57	1.82	2.14
11	2.98	1.45	1.65	2.03
12	2.84	1.34	1.52	1.95
13	2.71	1.26	1.40	1.88
14	2.60	1.18	1.30	1.81
15	2.50	1.12	1.21	1.75
16	2.40	1.06	1.14	1.69
17	2.33	1.01	1.07	1.65
18	2.27	.96	1.01	1.61
19	2.20	.92	.96	1.57
20	2.17	.89	.91	1.56
21	2.16	.85	.87	1.56
22	2.14	.82	.83	1.56
23	2.13	.80	.79	1.56
24	2.12	.77	.76	1.56
25	2.11	.75	.73	(6)
26	2.10	.73	.70	(6)
27	2.10	.71	.67	(6)
28	2.09	.69	.65	(6)
29	2.08	.67	.63	(6)
30	2.08	.66	.61	(6)

[1] Total cost, including overhead, but excluding hauling to beet dump or factory.

[2] Includes lifting with tractor and lifter, and hand pulling, topping, and loading.

[3] Including an allowance of 20 cents per ton loss in value of beet tops. This column is for the 2-row spike-wheel machine used to harvest 250 acres annually.

[4] The 1-row hand sorting machine, used to harvest 125 acres annually.

[5] Custom operators usually furnish hand gleaners as a part of the harvesting contract.

[6] Information unavailable.

two-row machine) is roughly half the cost of hand harvesting, although the cost of machine harvesting 30-ton beets is only a third as much as the cost of hand harvesting.

CUSTOM HARVESTING AND RENTING MACHINES AS POSSIBILITIES ON SMALL ACREAGES

One in four California growers had less than 25 acres of beets in 1949 (table 20). Those farmers who grow only a small acreage of sugar beets may find that owning a machine harvester is not economical. These growers should look into the possibilities of custom harvesting, of renting a machine and operating it themselves, or of buying a machine and doing custom work for others.

The usual charge for custom harvesting in 1948 was $1.65 per ton ($28.05 per acre) when the yield was 17 tons per acre. As a comparison, the usual cost of hand harvesting was about $2.33 per ton ($39.67 per acre). Custom harvesting was therefore more economical than hand harvesting (fig. 12). For other yields the usual custom harvesting charges were as follows:

When the yield was	*The custom charge was*
10 tons	$2.14 per ton
15 tons	$1.75 per ton
20 tons	$1.56 per ton

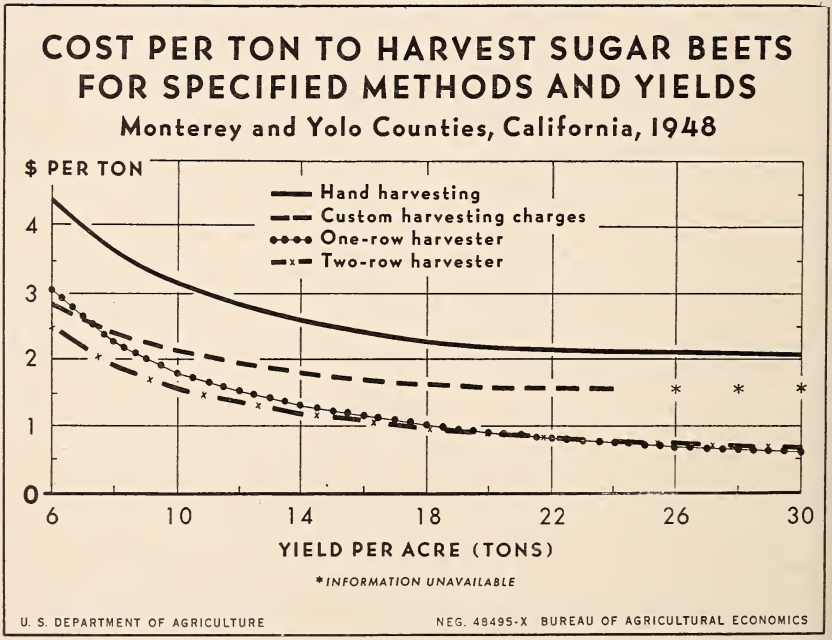

FIGURE 12.—Cost per ton to harvest sugar beets decreases as the yield per acre increases, irrespective of the method of harvest. Mechanical harvesting costs decrease faster, proportionately, than do hand harvesting costs, and the economic advantage of mechanical harvest is greatest with high yields.

A small grower may have an opportunity to rent a beet harvester and operate it himself. When spike-wheel harvesters first came into use, many were owned by the sugar companies. These companies rented them to growers at a fixed charge per acre of beets harvested. This charge covered maintenance and repair, depreciation, taxes, shelter, and interest on investment. The grower used his own tractor and furnished all operating labor, fuel, and lubricants. With this arrangement, the cost of harvesting beets included harvester rental $10.00,[27] labor, $5.76, use of tractor $2.74, fuel and lubricants for harvester, $0.36, loss in value of beet tops $3.40, or a total of $22.26 per acre, which was much lower than the cost of hand harvesting.

No instances were found in the survey of any one-row, hand-sorting harvester that was rented; therefore, no established rental charges are known. Farmers who wish to rent machines and other farmers who have machines for rent can negotiate equitable rental charges by referring to the information on costs of operation presented herein and to local experience. In particular instances the charges would depend upon the items of cost each party bears.

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[27] The usual rental charge per acre for a two-row spike-wheel harvester in 1948. Rental on the one-row model was $7.50 per acre.

ADDITIONAL TABLES

TABLE 13.—*Labor required per ton in harvesting sugar beets by hand and by machine at specified yields per acre, Monterey and Yolo Counties, 1948* [1]

Yield per acre (tons)	Hand harvesting [2]	Machine harvesting	
		2-row machine [3]	1-row machine [4]
	Man-hours	*Man-hours*	*Man-hours*
6	3.22	0.90	1.63
7	2.94	.77	1.40
8	2.71	.68	1.22
9	2.53	.60	1.09
10	2.39	.54	.98
11	2.25	.49	.89
12	2.15	.45	.82
13	2.04	.42	.75
14	1.95	.38	.70
15	1.87	.36	.65
16	1.80	.34	.61
17	1.73	.32	.58
18	1.68	.30	.54
19	1.62	.28	.52
20	1.57	.27	.49
21	1.53	.26	.47
22	1.48	.24	.45
23	1.45	.23	.43
24	1.42	.22	.41
25	1.38	.22	.39
26	1.36	.21	.38
27	1.34	.20	.36
28	1.32	.19	.35
29	1.31	.19	.34
30	1.31	.18	.33

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[1] Excluding hauling to beet dump or factory.

[2] Including lifting (1.4 man-hours per acre) and hand pulling, topping, and loading (varies with yield).

[3] With a crew consisting of tractor driver, harvester operator and one gleaner.

[4] With a crew consisting of tractor-harvester operator and two sorting men used two-thirds of the time.

TABLE 14.—*Estimated cost of harvesting sugar beets with tractor, beet lifter and hand topping and loading, Monterey and Yolo Counties, 1948* [1]

Item	Total	Average costs per	
		Acre	Ton [2]
	Dollars	*Dollars*	*Cents*
Lifter cost:[3]			
Maintenance and repair [4]	6.50	0.05	0.3
Taxes and insurance	1.43	.01	.1
Shelter	.64	.01	[5]
Depreciation [6]	23.83	.19	1.1
Interest on investment [7]	7.15	.06	.3
Total	39.55	.32	1.9
Tractor cost:			
Overhead [8]	179.48	1.44	8.4
Fuel	62.00	.50	2.9
Lubricants	17.88	.14	.8
Total	259.36	2.08	12.1
Labor cost:			
Tractor driver	177.17	1.42	8.3
Topping and loading [9]	4,481.25	35.85	210.9
Total	4,658.42	37.27	219.2
Total cost	4,957.33	39.67	233.2

[1] Based on survey data adjusted to 125 acres harvested annually, and to 1948–49 prices.

[2] Assumes a yield of 17 tons per acre.

[3] Lifter consists of attachments to ditching tool; therefore charge to beets includes total costs of lifter attachment, and beet harvest share of basic ditching tool.

[4] Includes parts, hired shop work, farm shop work, and farm labor.

[5] Less than 1/10 cent.

[6] Original purchase price (1948) less assumed ending value divided by 10 years, equals annual depreciation.

[7] Assumed as 5 percent of the average value of the lifter during its life.

[8] Including maintenance and repairs, taxes, insurance, shelter, depreciation, and interest on investment Assumes one-fifth of annual use of tractor on beet harvest.

[9] Minimum scale established by Sugar Branch, PMA, plus 10 percent, plus $1.00 per acre for labor camp charge, plus $1.00 per acre bonus to crew foreman; the usual arrangements in the areas studied.

TABLE 15.—*Usual performance, labor, and materials in harvesting sugar beets with two-row spike-wheel harvesters, Monterey and Yolo Counties, 1948* [1]

Item	Unit	Average per			
		Harvester	Acre	Machine-hour	Ton
Acreage harvested	Acre	274.3	1.00	0.62	0.06
Beets harvested [2]	Ton	4,631.0	16.88	10.48	1.00
Harvester-tractor hours [3]	Hour	441.8	1.61	1.00	.10
Labor:					
Tractor driver	Hour	518.8	1.89	1.17	.11
Harvester operator	do	518.6	1.89	1.17	.11
Gleaners	do	645.6	2.36	1.46	.14
Total [4]	do	1,683.0	6.14	3.80	.36
Harvester:					
Fuel	Gallon	531.1	1.94	1.20	.11
Oil	Quart	57.9	.21	.13	.01
Grease	Pound	67.8	.25	.15	.01
Tractor:					
Fuel	Gallon	1,840.8	6.71	4.17	.40
Oil	Quart	155.5	.57	.35	.03
Grease	Pound	92.2	.34	.21	.02

[1] From the farm survey of 18 beet harvesters in the 1948 season.

[2] Clean basis (on which grower is paid).

[3] Includes normal stops for incidental service, adjustment and repair; each stop not exceeding 15 minutes.

[4] Primarily operating labor; excludes major repairs and seasonal overhaul.

TABLE 16.—*Usual cost of harvesting sugar beets with 2-row spike-wheel harvesters, Monterey and Yolo Counties, 1948* [1]

Item	Average cost per [2]—			
	Harvester	Acre	Machine-hour	Ton [3]
	Dollars	*Dollars*	*Dollars*	*Cents*
Harvester cost:				
Maintenance and repairs [4]	656.28	2.39	1.48	14.2
Fuel	98.61	.36	.22	2.1
Lubricants	18.72	.07	.04	.4
Taxes and insurance	33.00	.12	.08	.7
Shelter [5]	5.00	.02	.01	.1
Depreciation [6]	498.39	1.82	1.13	10.8
Interest on investment [7]	159.67	.58	.36	3.4
Total	1,469.67	5.36	3.32	31.7
Tractor cost:				
Overhead (beet share) [8]	367.17	1.34	.83	7.9
Fuel	211.56	.77	.48	4.6
Lubricants [9]	48.44	.18	.11	1.1
Total	627.17	2.29	1.42	13.6
Labor cost:				
Tractor driver	582.33	2.12	1.32	12.6
Harvester operator	613.44	2.24	1.39	13.2
Gleaners [10]	557.22	2.03	1.26	12.0
Total	1,752.99	6.39	3.97	37.8
Total harvesting costs	3,849.83	14.04	8.71	83.1

[1] From farm survey of beet harvest in 1948 season.

[2] For 18 harvesters which harvested 4,937 acres, 83,358 tons (clean basis) during 1948 season.

[3] Average yield was 16.88 tons (clean basis) per acre.

[4] Including parts, hired shop work, farm shop work, and farm labor (used in major repairs).

[5] Assumed at $5.00 per machine per year.

[6] Original purchase price less ending value divided by 10 years equals annual depreciation.

[7] Assumed at 5 percent of the average value during life of the machine.

[8] Including maintenance and repairs, taxes, insurance, shelter, depreciation and interest on investment. Beet harvest took 34.4 percent of the annual use of tractors used.

[9] Includes oil-filter cartridges.

[10] Gleaner labor was used on 69 percent of the acreage harvested.

TABLE 17.—*Usual performance, labor, and materials in harvesting sugar beets with one-row hand-sorting harvesters, Yolo County, 1948* [1]

Item	Unit	Average per—			
		Harvester	Acre	Machine-hour	Ton
Acreage harvested	Acre	86.8	1.00	0.28	0.06
Beets harvested [2]	Ton	1,370.4	15.79	4.36	1.00
Harvester hours [3]	Hour	314.0	3.62	1.00	.23
Labor hours:					
Tractor driver	Hour	373.0	4.29	1.19	.27
Sorting men	do	518.0	5.96	1.65	.38
Total [4]	do	891.0	10.25	2.84	.65
Fuel	Gallon	535.5	6.17	1.70	.39
Oil	Quart	36.7	.42	.12	.03
Grease	Pound	74.4	.86	.24	.05

[1] From survey of 11 beet harvesters in the 1948 season.

[2] Clean basis (on which grower is paid).

[3] Includes normal stops for incidental service, adjustment and repair; each stop not exceeding 15 minutes.

[4] Primarily operating labor; excludes major repairs and seasonal overhaul.

TABLE 18.—*Usual cost of harvesting sugar beets with 1-row hand-sorting harvester, Yolo County, 1948* [1]

Item	Average cost per [2]—			
	Harvester	Acre	Machine-hour	Ton [3]
	Dollars	*Dollars*	*Dollars*	*Cents*
Harvester cost:				
Mount and dismount [4]	45.73	0.53	0.15	3.3
Maintenance and repair [5]	195.17	2.25	.62	14.2
Lubricants	7.64	.09	.02	.6
Taxes and insurance	16.36	.19	.05	1.2
Shelter [6]	3.00	.03	.01	.2
Depreciation [7]	173.92	2.00	.56	12.7
Interest on investment [8]	81.73	.94	.26	6.0
Total	523.55	6.03	1.67	38.2
Tractor cost:				
Overhead (beet share) [9]	98.27	1.13	.31	7.2
Fuel	84.27	.97	.27	6.1
Lubricants [10]	9.00	.10	.03	.7
Total	191.54	2.20	.61	14.0
Labor cost:				
Tractor driver	451.64	5.20	1.44	33.0
Sorting men [11]	527.27	6.08	1.68	38.4
Total	978.91	11.28	3.12	71.4
Total harvesting cost	1,694.00	19.51	5.40	123.6

[1] From survey of beet harvest 1948 season.

[2] For 11 harvesters which harvested 954.9 acres, 15,075 tons (clean basis) during season.

[3] Average yield was 15.79 tons (clean basis) per acre.

[4] Mostly labor of grower; includes gaskets, etc. for mounting.

[5] Includes parts, hired shop work, farm shop work, and farm labor.

[6] Assumed at $3.00 per harvester per year.

[7] Original purchase price less ending value divided by 10 years equal annual depreciation.

[8] Assumed at 5 percent of the average value during life of the machine.

[9] Including maintenance and repairs, taxes, insurance, shelter, depreciation and interest on investment. Beet harvest took 35.8 percent of the annual use of tractors used.

[10] Includes oil-filter cartridges.

[11] 2 sorting men were used on 55 percent, 1 man on 24 percent, and no men on 21 percent of total acreage harvested.

TABLE 19.—*Trend in planted acreage of sugar beets, by areas in California, 1946–51*

Sub-area [1]	1946	1947	1948	1949	1950	1951 [2]
	1,000 *acres*	1,000 *acres*	1,000 *acres*	1,000 *acres*	1,000 *acres*	1,000 *acres*
Sacramento and North San Joaquin Valleys	54	50	66	79	93	61
South San Joaquin Valley	15	20	21	8	26	4
North Central Coast	37	48	43	29	44	31
Southern California	15	18	11	12	20	14
Imperial County [3]	14	25	40	17	33	32
Total	135	161	181	145	216	142

[1] Areas defined as in footnotes to table 2.

[2] Preliminary estimates from unpublished data.

[3] Includes acres planted previous fall for harvest in calendar year indicated.

From annual reports of Production and Marketing Administration, Berkeley.

TABLE 20.—*Estimated number of sugar beet growers having specified acreages of beets in California, 1949* [1]

Acres of beets per grower	Number of growers	Percentage of growers
	Number	*Percent*
Under 25	388	26
25–49	253	17
50–74	270	18
75–124	258	18
125–249	203	14
250–349	58	4
350–549	23	2
550 and over	15	1
Total	1,468	100

[1] Estimate based on size groupings of sugar payments to growers in Annual Report, Production and Marketing Administration, Berkeley, October 1950.

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